

WEALTH OF THE OCEANS

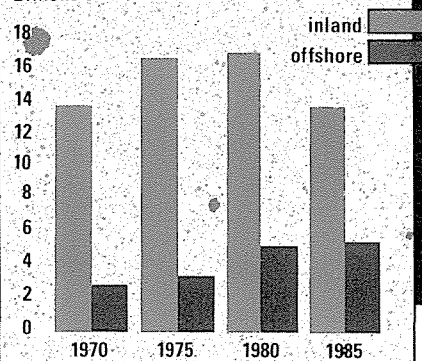
Tony Stone Worldwide

THE OCEANS AND THE SEAS present many challenges. They contain enormous quantities of materials valuable to Man. But, in most cases, obtaining these materials presents great difficulties or dangers.

The oceans abound with useful minerals, but most are too costly to extract from the vast volumes of water. Oceans cover more than 360

million square km of the Earth's surface, and contain around 1,400 million cubic km of water. Fish, on the other hand, are relatively easy to catch and Man could very easily endanger future supplies by over-fishing. Although the oceans are a tempting dumping ground for waste products, there is an urgent need to avoid harming plant and animal life by polluting the waters with sewage and chemical waste.

Billions of barrels:



WORLD OIL

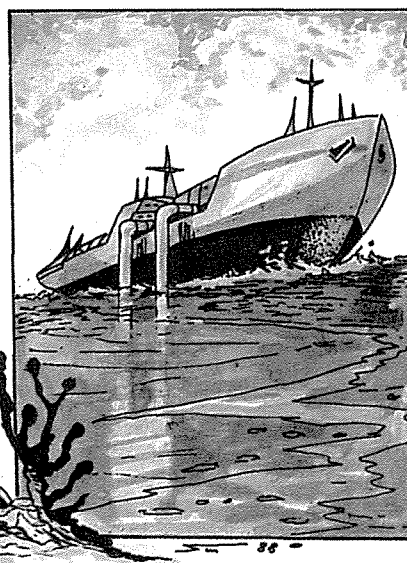
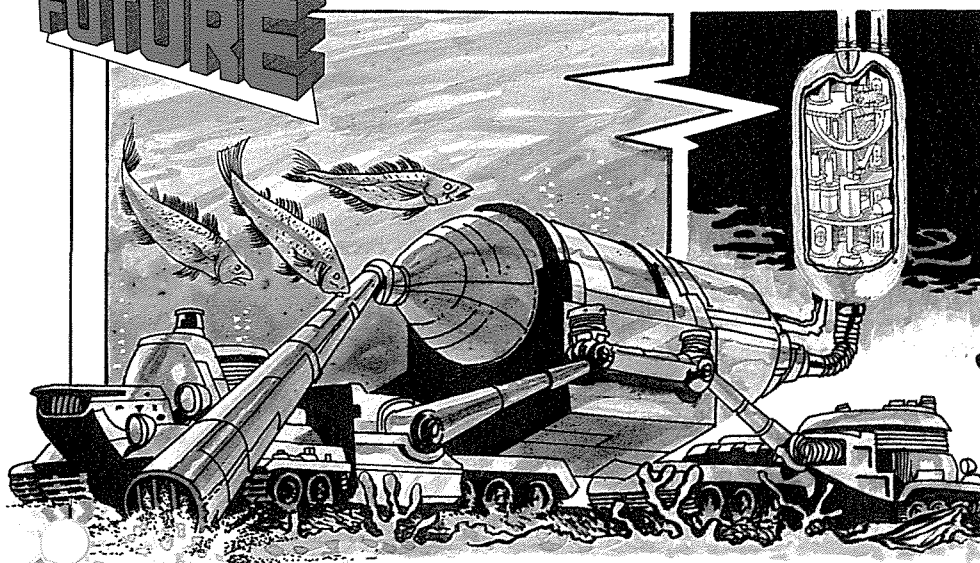
PRODUCTION

The increase in world oil consumption since 1970 has led to a rapid increase in offshore drilling. By the mid-1980s it contributed about 28 per cent to world production.

Mark Franklin

INTO THE FUTURE

HARVESTING THE OCEANS

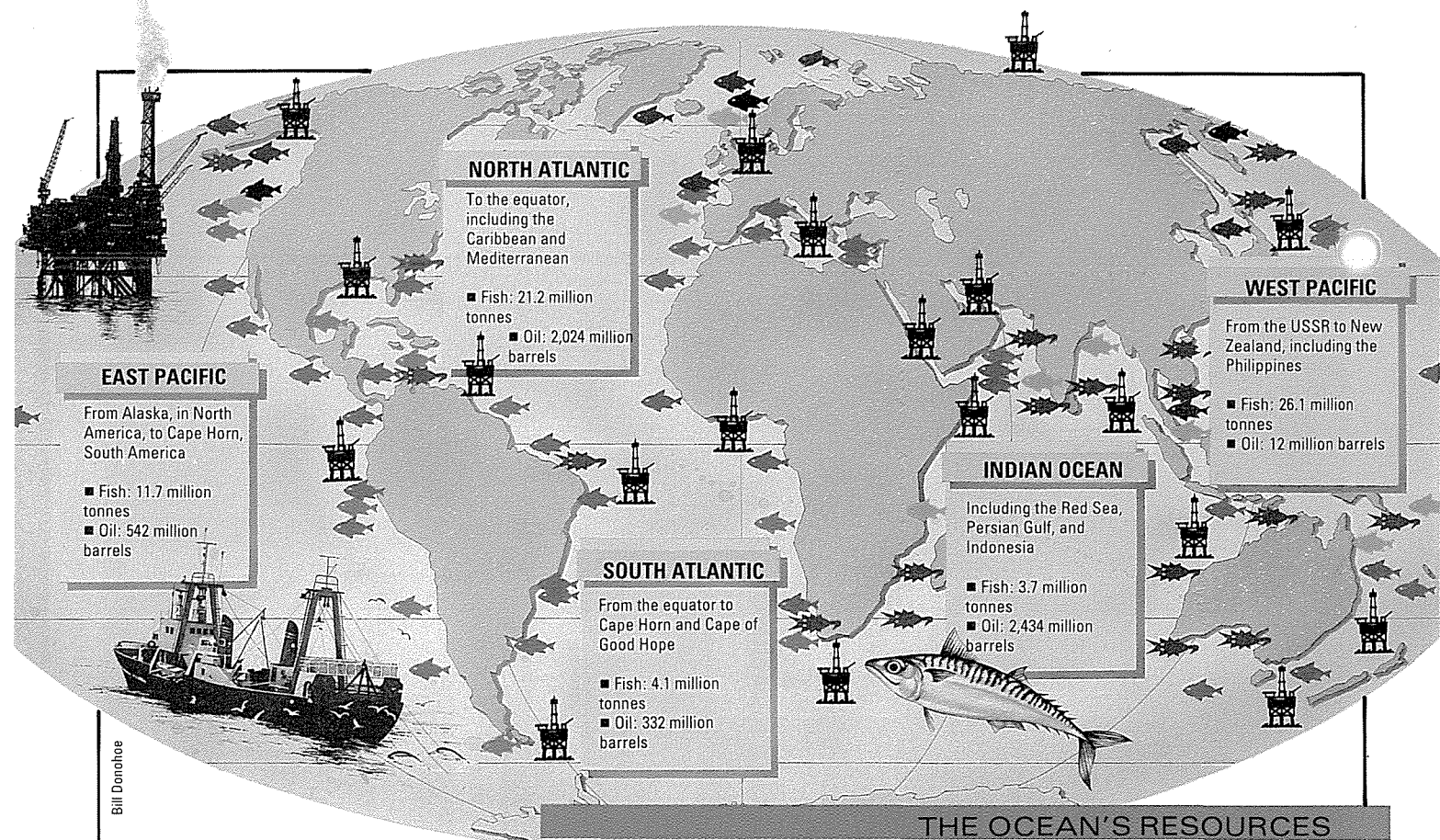


Alan Burrows

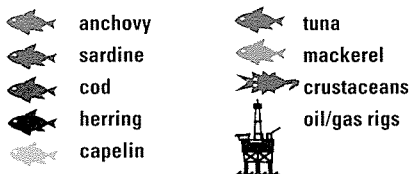
▲ Powerful underwater tractors could be employed to harvest mineral-rich manganese nodules that lie scattered over the ocean floor.

▲ Manganese nodules would be sucked up and passed through a tube to a nearby processing chamber where they would be ground down to a powder.

▲ From the chamber, manganese powder would be transferred to the hold of the mother ship, then taken to a refinery where precious metals would be extracted.



KEY



The symbols show the most important areas in the world's oceans for fishing and oil production. The most productive regions for oil and natural gas lie close to the edges of the continents. Some coastal waters also yield some coal and metals, notably iron, titanium and tin.

Offshore oil production started in California in the 1890s and, as recently as 1960, about 90 per cent of offshore rigs were

around the coasts of the United States. Since then, the great potential of offshore oil reserves has been exploited by many other countries. Now, more than three-quarters of all oil rigs are in other regions.

Whereas oil reserves are certain to become used up, the oceans' fish resources could provide us with food indefinitely. However, the rate at which fish are taken will have to be carefully regulated to ensure that stocks are maintained.

Gold, silver and uranium are among the 58 billion tons of solids in the oceans. But these precious metals occur in such minute quantities that the cost of extracting them would be more than their value – at least, at present. On average, each one million tonnes of sea water contains about 1,500 g of uranium, 300 g of silver, and only 6 g of gold.

Mineral wealth

Magnesium is the most valuable substance extracted, but common salt is taken in the greatest amounts. However, it is the ocean floor that yields most of the mineral resources. Vast oil and gas reserves locked beneath the surface are tapped through boreholes. About 250 wells are in operation in the North Sea alone. Yet the North Sea is one of the most inhospitable seas on the planet. With waves up to 25 metres high and winds of 200 km/h, living conditions on North Sea rigs are particularly dangerous. Rescue from these rigs, in the event of an accident, is fraught with danger.

In the deep oceans, especially below 4,500 metres, strange pota-

to-shaped deposits known as manganese nodules are found. These are packed full of valuable materials – not just manganese, but also nickel, cobalt and copper. So too are the manganese crusts, which occur as coatings several centimetres thick on some rocks. These are found in shallower waters.

Manganese nodules will become an important source of metals once scientists have developed an economic method of collecting them.

Watery treasures

Pearls come from oysters, which were once gathered by skin divers. Nowadays, pearl culture is a highly organized business, especially in Japan. To start a pearl developing, a small 'nucleus' is placed within the soft tissue of the oyster. The original pioneers used small glass beads and lead shotgun pellets. Shell pellets are used now as they work much better.

Fifty years ago, it was a struggle to make cultured pearls even 3 mm across. Now they may be as large as 10 mm. Despite their impressive size, they consist mostly of the

nucleus. The outer pearly layer is beautiful and translucent, but only a few millimetres thick.

Precious coral is a type of sea fan that lives only in deep water. Delicate pink jewellery is made from this creature by skilfully working the stem of the fan.

Sea food

Huge amounts of food are present in the oceans, but only about three per cent of the world's food supply actually comes from the sea. One reason for this is that many people, especially in the West, are not great eaters of seafood. In the Far East, people are much more adventurous. Strange creatures such as sea cucumbers are a favourite among the Chinese, who also eat jellyfish and sea urchins.

Another unusual sea food is the Pacific palolo worm. In Polynesia, a great feast is held every year to celebrate the spawning of this sea creature. When the reproductive hind ends of the worms are cast off into the water, they are scooped up in enormous quantities. This strange harvest is then made into soup.

SKIN DIVING FOR DRUGS

Black coral is collected by skindivers from the sea in the Antilles – an island group between the Caribbean Sea and the Atlantic Ocean.

This form of coral is an important source of prostaglandin – a hormone-like substance used to induce labour. Before this source was discovered, only tiny amounts were available from mammals.



Planet Earth Pictures/Krov Menubhin

Around 75 million tonnes of fish are taken from the oceans each year. Anchovies, herrings and sardines are all small, shoaling fishes that feed on tiny organisms floating in the water. Bigger fish, such as mackerel and tuna usually eat the smaller species.

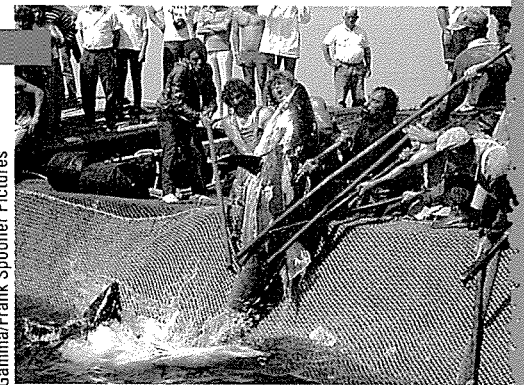
The seaweed crop is tiny compared with that of land plants. Most seaweeds are too small to collect as food. And even the larger species are not highly nutritious. However, in the Far East about a million tonnes of wet weed are taken each year for food. Much of this seaweed is cultivated.

Drugs and plunder

Many compounds have been discovered in ocean plants and animals. Some can fight disease, while others stimulate the heart, control blood clotting, or influence the workings of the nervous system. Cytotoxins, from sea cucumbers and sea fans, are important in destroying cancer growths. And black

TACKLING THE TUNA

Bringing tuna aboard a fishing boat in the Mediterranean Sea is the first stage in a production line that ends up with the tin on a supermarket shelf. This huge, agile creature eats large quantities of smaller fish, and outweighs a man by the time it has reached the age of five years. It commonly weighs around 200 kg at the age of ten, and it doubles this weight by the age of 25 – if it is fortunate enough to live that long.



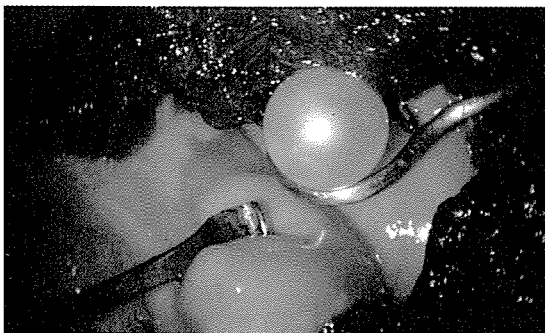
Gamma/Frank Spooner Pictures

corals provide prostaglandins used to stimulate muscle contractions.

Throughout history, pearls have been thought to have medicinal properties. Claims are made that pearl powder can cure indigestion, malaria, leprosy, insomnia and many other ills. However, scientists are not yet convinced that such claims are anything more than mere superstition.

Big boats, modern fishing gear

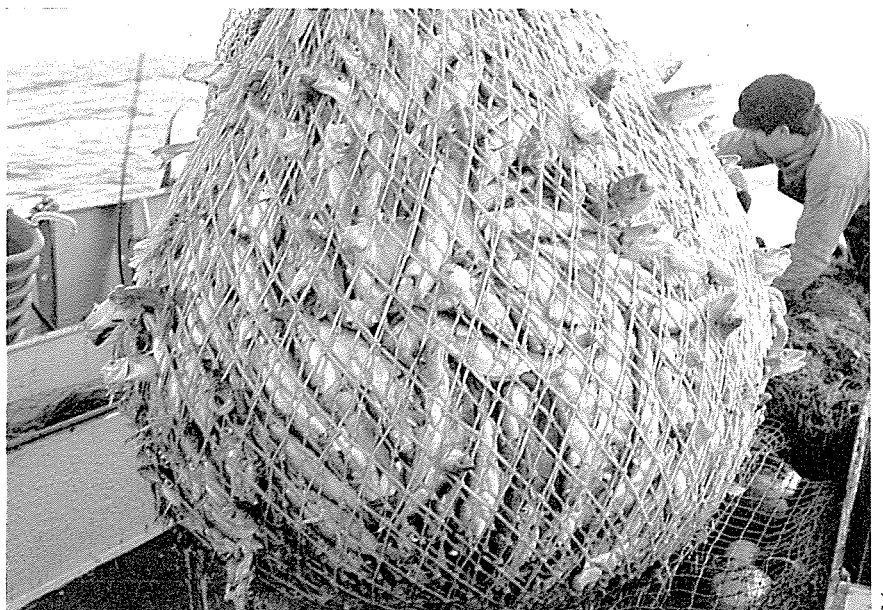
and sonar systems to detect fish heralded the beginnings of serious over-fishing. These innovations meant that, instead of just a few fish being caught, they were scooped from the water by the tonne. As more boats and fishermen joined the hunt, working long hours out at sea, the harvest became enormous. Now warning bells are sounding, for those species being exploited are on the decline.



Michael Freeman

A cultured pearl is revealed for inspection by the latest photographic techniques, allowing us to see inside a live oyster.

Cod and haddock is hauled aboard a 'wet-fish' trawler in the North Sea. The catch is brought back to shore to be frozen.



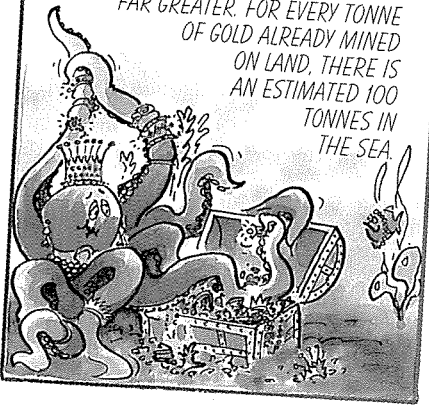
Zefa

WEALTH OF THE OCEANS

Just amazing!

LIQUID GOLD

ALTHOUGH MAN CONTINUES TO MINE THE EARTH'S RESOURCES AS FAST AS HE CAN, THE OCEANS' WEALTH IS FAR GREATER. FOR EVERY TONNE OF GOLD ALREADY MINED ON LAND, THERE IS AN ESTIMATED 100 TONNES IN THE SEA.



Paul Raymond

In the North Sea, some stocks of herring and mackerel dropped to a point where tight controls and catch quotas had to be introduced to allow the populations to recover.

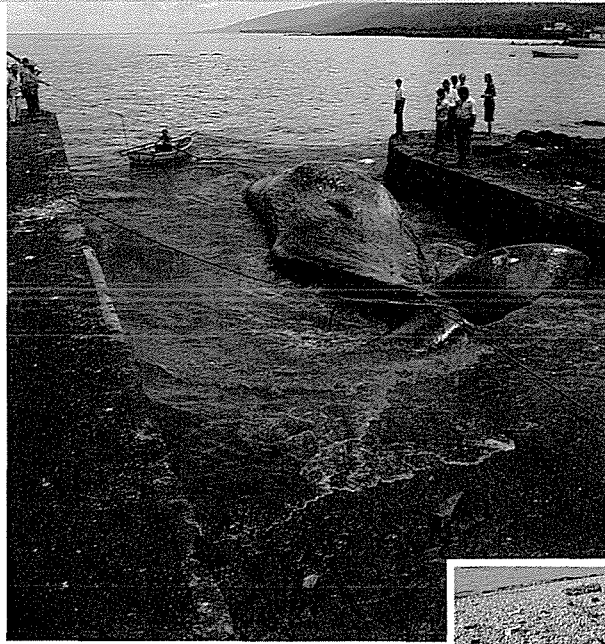
The exploitation of whales is one of the saddest stories of all, partly because of the inhumanity involved in the slaughter of these intelligent giants. Since commercial whaling began over one hundred years ago, some species have been brought to the brink of extinction.

The blue, humpback and bow-head whales have all become endangered, with populations dropping to as little as one tenth of their original level. International legislation has now been introduced, but some nations are unwilling to cooperate with the restrictions and so these whales are still under threat.

Man – the polluter

The seas are immense, and it is tempting to assume that waste dumped there will be diluted and whisked away by the currents. Sometimes this is true, but not always. Huge quantities of waste are involved, most of it is dumped in shallow coastal waters, and some of it is extremely dangerous. Besides sewage, toxic heavy metals, such as lead, mercury and cadmium are dumped in the sea. In the 1950s, over 2,000 people were poisoned, 43 killed and 700 permanently disfigured at Minamata in Japan, after eating fish and shellfish contaminated with mercury from a local factory.

Dangerous pesticides also wash into the oceans, either directly or via rivers. These substances are taken up by marine plants and animals,



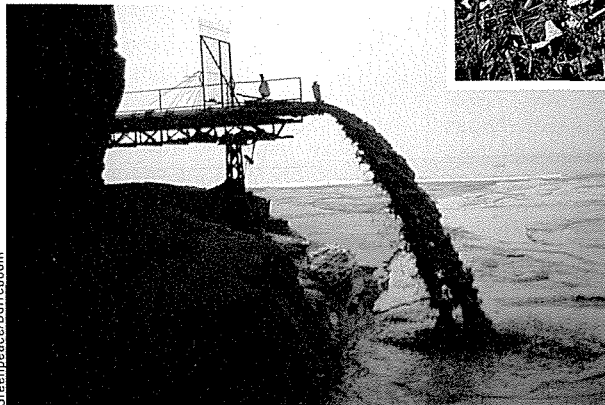
Planet Earth Pictures/Jonathan Gordon

A sperm whale is pulled ashore – its blood turning the sea red. The location is Pico, one of the Azores islands in the North Atlantic. The sperm whale is the largest of the toothed whales. When fully grown, it reaches more than 18 metres in length. Despite warnings about endangering the whale population, some countries still allow these huge creatures to be caught.

Waste dumped from ships is eventually washed up on to the beaches by the tides. It has been estimated that a staggering 7 million tonnes of litter is dumped into the oceans every year.



Zela



Greenpeace/Durreboom

The Mediterranean has about 30 million tonnes of sewage pumped into it every day. Plankton feed off this sewage, and use up all the oxygen in the water, causing fish to die.

DANGER TO WILDLIFE

The most polluted regions of the ocean are close to the land, where most of the world's fish are found. But it is not only marine life that is threatened. Birds can also meet their fate in floating oil masses.



Zela

and can badly affect their growth and health. Worse still, they often accumulate both in the environment and in living organisms. In this way they enter food chains and become more concentrated at each link in the chain.

Oil pollution

When oil spills occur, they hit the headlines because of the mess and the way that the oil blankets the sea, choking birds to death and smothering sea-shore life. Between 0.5 and 1.0 million tonnes of oil enter Mediterranean waters every year, making it one of the most chronically oil-polluted areas in the world.

Fortunately, however, oil is biodegradable. This means that, in time, bacteria and other micro-organisms will get to work on the oil and eventually break it down into harmless compounds. In the early days, oil spills were treated with detergents, but this proved to be more damaging to marine life than the oil. Now, the policy is to try to contain the spill and stop it from reaching vulnerable areas.

Planet Earth Pictures/Rob Beighon

Q GAS RIGS

Q GENERATING STATIONS

Q NUCLEAR POWER

Air pollution from coal-fired power stations is reduced by fitting them with devices that remove sulphur, dust and grit from the waste gases.

POWER TO THE PEOPLE

FLIP A SWITCH AND, AS IF BY magic, an electric light comes on — or a radio, a vacuum cleaner, or a heater. Twist a knob and a glowing ring of gas flames obediently springs from a cooker.

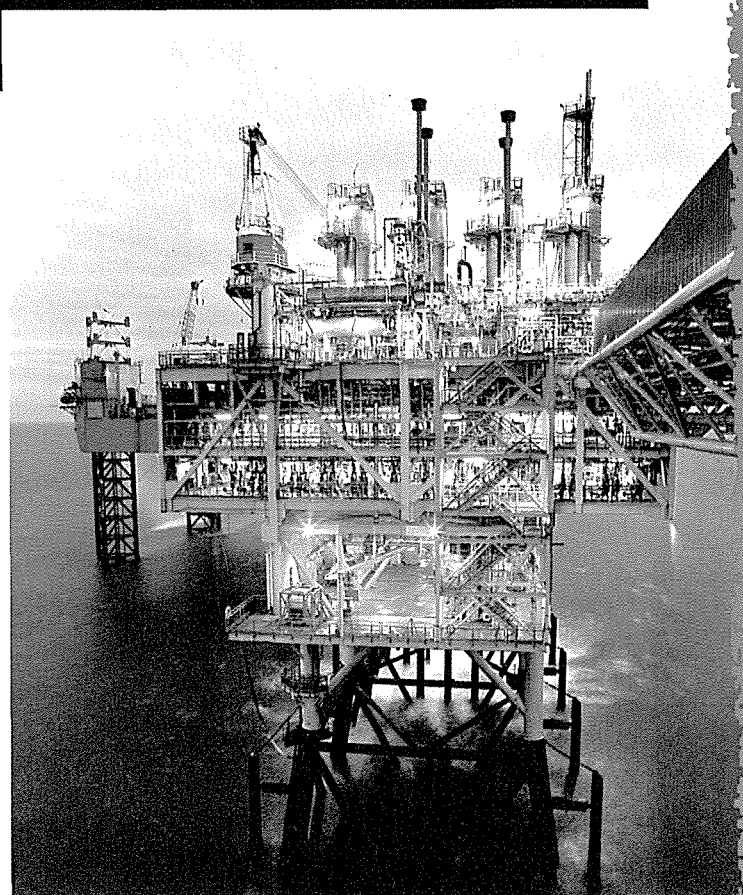
We take such things for granted, but whenever a supply is interrupted, it soon becomes obvious

how totally dependent we are on these vital services.

There is far more to a city, a village, or even a single house, than meets the eye. Below ground level, safe from disturbance, cables and pipes convey electricity and gas into the very heart of our homes. Without these 'mains' services, our life-style would be quite different.

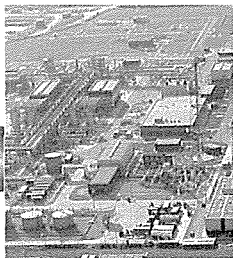
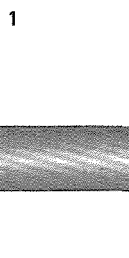
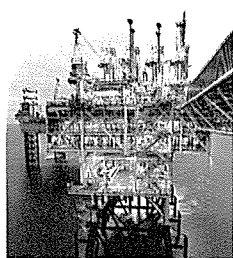
Natural gas from huge offshore drilling rigs has replaced the coal gas previously produced at gasworks throughout the country.

The modern gas industry has its origins in the late eighteenth century development of gas lighting. The use of gas for cooking and heating began in the middle of the



British Gas PLC

GAS – FROM RIG TO CONSUMER



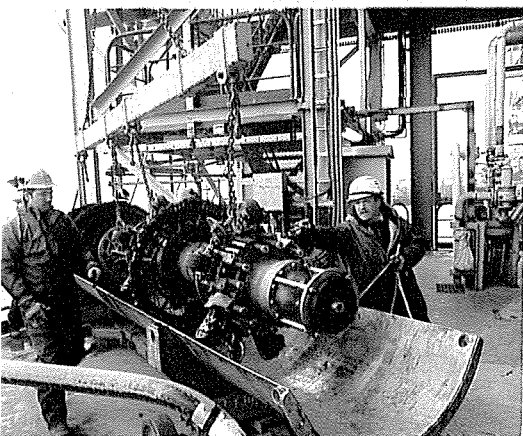
Huge rigs (1) recover natural gas from below the sea bed. This gas was produced by chemical reactions on the bodies of tiny sea creatures that died hundreds of millions of years ago.

Gas is piped to an on-shore terminal (2), where impurities are removed. Tests are carried out to check that the gas produces the right amount of heat, and a smell is added so that leaks can be detected.

Compressor stations (3) boost pressure at intervals along the major supply pipes. Reduction stations and regulators keep local supplies at a lower pressure. Gas storage (4) helps to cope with demand.

British Gas PLC

THE INTELLIGENT PIG



British Gas PLC

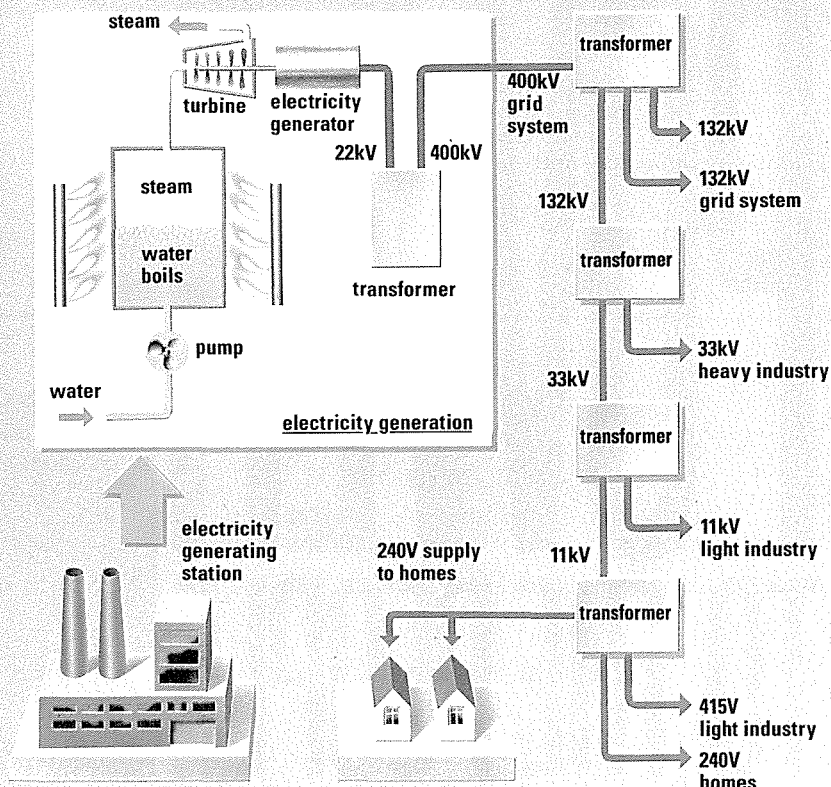
High-pressure gas pipelines need regular inspections. British Gas use a computerized intelligent device called the pig, which is driven along the pipes by gas pressure. It records about 750,000 measurements each second. On a typical inspection, it records 2,100 million measurements.

nineteenth century with the introduction of gas stoves in 1840 and gas fires in 1855. At first, most of the gas was manufactured by heating coal in the absence of air. The use of natural gas was started by the Fredonia Gas Light and Water Works Company in the US in the year 1858.

In many parts of the world there are valuable deposits of natural gas,

either in association with oil or on their own. Natural gas consists mainly of methane, together with ethane and small amounts of propane, butane and nitrogen. This gas was once considered as little more than a nuisance when discovered during drilling for oil, and was merely disposed of by burning it at the oilfields. This is still done in many areas, particularly at oilfields in re-

ELECTRICITY GENERATION AND DISTRIBUTION



In an electricity generating power station, heat from burning coal or oil, or from a nuclear reaction, boils water to produce steam. This rotates the blades of a turbine, which turns an electricity generator. A transformer changes the 22,000 volt alternating current (22 kV

AC) output from the generator up to 400 kV, as power losses are greatly reduced by transmitting electricity at a high voltage. During its distribution around the country, other transformers reduce the voltage of this major supply in stages.

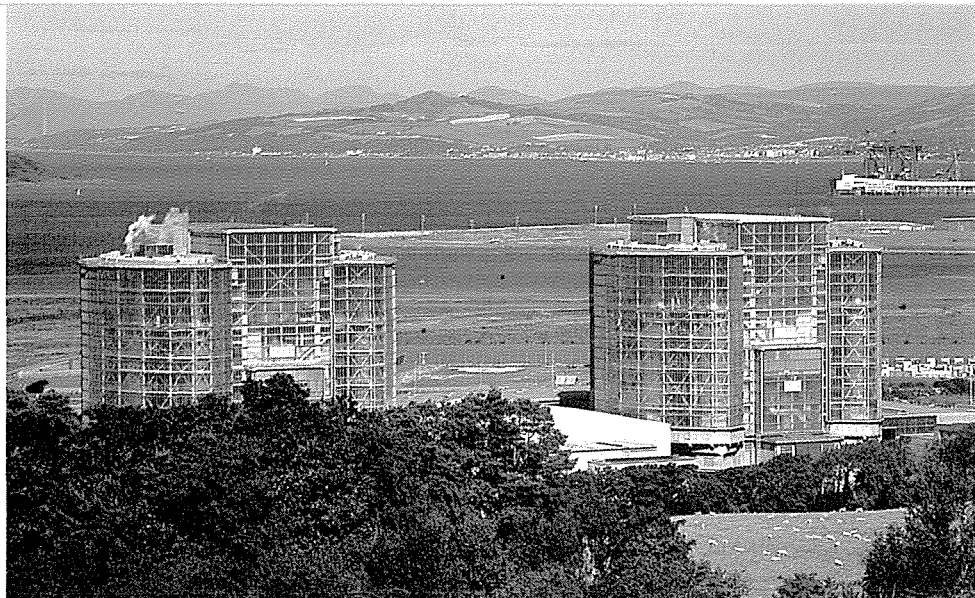
Janos Marffy

Just amazing!

THIRSTY WORK
THIRD-WORLD CITIZENS USE MUCH LESS FUEL THAN PEOPLE IN DEVELOPED COUNTRIES. IN NEPAL, FOR EXAMPLE, THE AVERAGE PERSON USES ONLY ONE-THOUSANDTH AS MUCH FUEL AS A CITIZEN OF THE US.



Paul Raymond

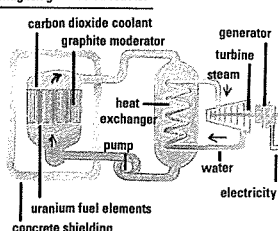


POWER TO THE PEOPLE

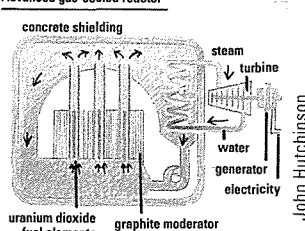
The nuclear power station at Strathclyde, Scotland. The two main buildings house a Magnox reactor and an Advanced Gas-cooled Reactor (AGR). The Magnox reactor uses uranium fuel, while the AGR uses enriched uranium dioxide. In both types, carbon dioxide gas absorbs heat produced in a carefully controlled nuclear reaction and transfers it to water via a heat exchanger. The water changes into steam, which turns a turbine linked to an electricity generator. The electricity is then distributed through the National Grid.

The Magnox reactor's heat is carried by carbon dioxide around water-filled tubes. The water boils, and the steam drives a turbine and generator. In the AGR, water boils as it passes through the nuclear fuel chamber.

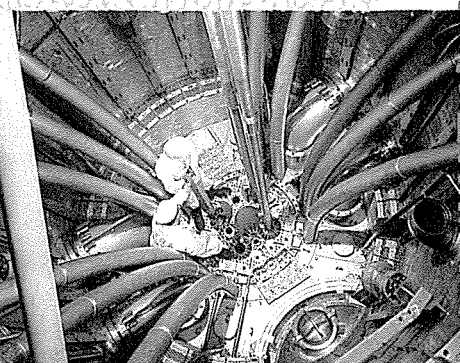
Magnox gas-cooled reactor



Advanced gas-cooled reactor



THE HOT SPOT



John Hutchinson
US Dept. of Energy SPL

The core of a nuclear reactor is where matter is converted into large amounts of energy, in accordance with Einstein's mass-energy equation: $E = mc^2$. The symbol c represents the speed of light, which is very great, so c^2 , or $c \times c$, is enormous. This is why the energy (E) produced by destroying a mass (m) is so great.

mote desert areas far from any potential consumers of gas.

Today, however, many oil-producing countries collect and process this gas, either for export in liquefied form or to provide fuel for their own developing industries and cities.

Natural gas became the major source of gas in the US in the 1930s, following the discovery of extensive deposits and improve-

ments in pipeline technology. There are now over 100,000 natural gas wells in the United States alone. Extensive natural gas deposits have also been found in North Africa, Russia, Australia and off the northern European coast.

North Sea gas

In Europe, one of the most significant finds of natural gas was made at Groningen, northern Holland. This strengthened the opinions of many geologists who believed that there was gas, and possibly oil, in vast quantities under the North Sea between Britain and Holland.

The first commercial find in the North Sea was made in 1965. Exploration and discovery made steady progress, and the gas was soon being piped ashore for use in Britain. Gas from beneath the bed of the North Sea is now the primary source of gas for Britain and other northern European countries.

North Sea gas is brought by pipeline from offshore drilling rigs to coastal reception terminals, and distributed by a network of more than 3,000 km of high-pressure pipelines. The gas is taken from these main pipes and distributed locally at lower pressures.

Electricity

Imagine what it would be like with no record players, tape recorders, TVs, radios and refrigerators, not to mention electric lights and heaters. Yet, about a century ago, before the arrival of domestic electricity, no-one had any of these things in their home.

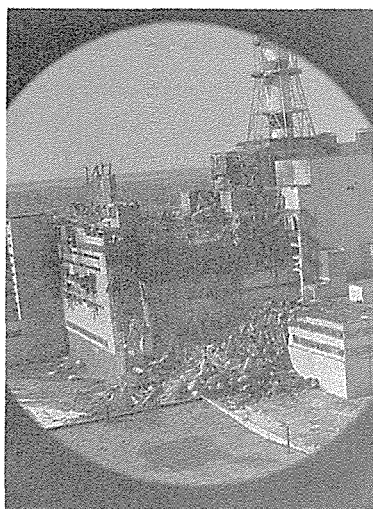
It was the invention of the incandescent electric light bulb in about 1879 that initiated the public

demand for electrical energy, but the new form of energy was soon being used to provide heat and also power for machines. The cleanliness and flexibility of use, and the simplicity of transmission from one place to another, rendered it popular with domestic, commercial and industrial users alike.

The first public electricity supply systems were owned and operated by private companies or by local authorities. Some systems provided direct current (DC), which flows in one direction only, like the current from a battery. Others provided alternating current (AC), which rapidly alternates, or changes its direction of flow. The voltages of the various supplies differed, and the frequencies (rates of alternation) of the alternating current supplied varied too.

As the use of electricity grew, it became obvious that the supplies should be standardized throughout the country. This would not only permit the easy transmission of

CHERNOBYL DISASTER



Rex Features

In the early hours of 26 April 1986, the unthinkable happened at a nuclear power plant in the Ukraine, then part of the USSR – a nuclear reactor blew up. The disaster occurred because safety procedures were not strictly followed. About 30 people died immediately, but up to 75,000 people may eventually die.

power from one part of a country to another, but it would also simplify the design and construction of electrical equipment.

Standardization

In Britain today, the standard supply to the home is 240 volts AC. The electricity is produced by burning coal or oil, or by the breakdown of a radioactive substance like uranium. The heat from these fuels is used to produce steam to drive turbines linked to generators.

Alternating current has one great advantage over DC. Its voltage can be changed by means of a simple device called a transformer. This enables the electricity produced by generators at a power station to be converted to a much higher voltage for transmission along cables to other parts of the country. At a high voltage, less current is required to transmit a given amount of power. And the losses in the cable depend on the strength of the current. Therefore, by increasing the voltage and reducing the current, power losses are reduced, making the system much more efficient.

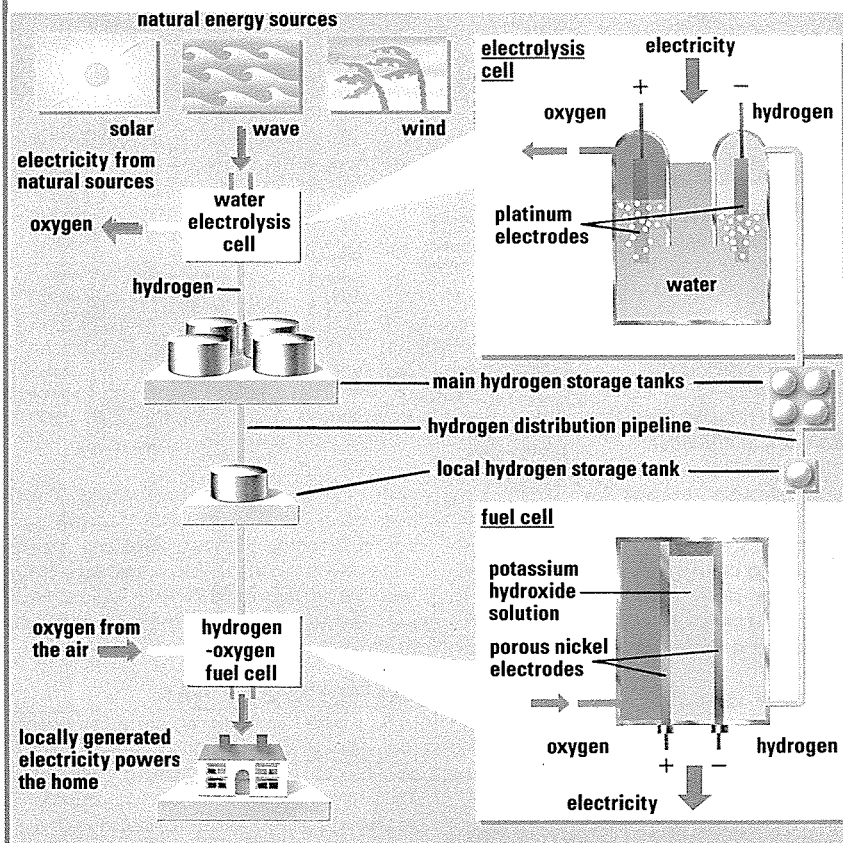
National supplies

In many countries, such as Britain and France, the establishment of national supply networks was followed by state ownership of the supply companies. But in 1990, most of the electricity industry in England and Wales became run by private companies again. In other countries, for example the US and Switzerland, the national network interconnects a mixture of private and public systems.

ALTERNATIVE ENERGY SOURCES

Electricity is an extremely convenient form of energy – clean, versatile and efficient. Work continues on developing effective ways of converting nature's forces, such as solar, wave, tidal and wind power, into electricity. The main problem is that the demand for electricity is not always matched by these forms of supply. What is needed is

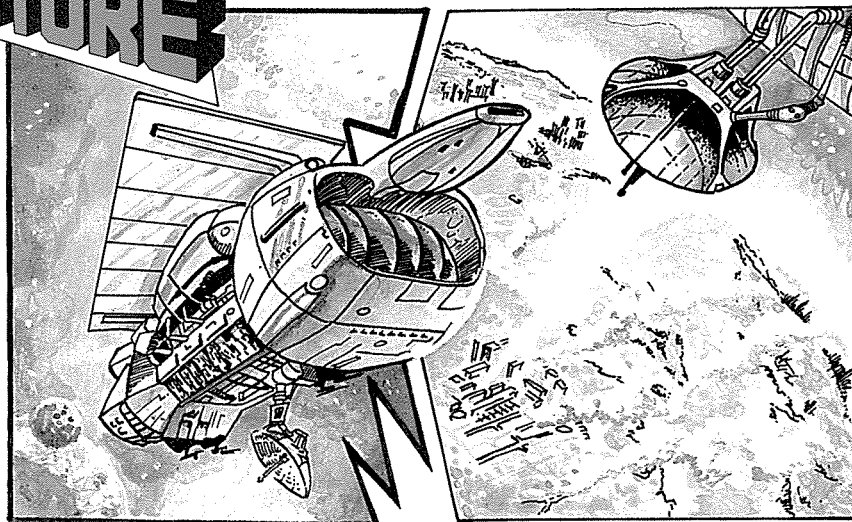
some kind of storage system so that the electricity is available when needed. One possible solution to the problem is to use electricity generated by natural forces to split water into hydrogen and oxygen (electrolysis). The hydrogen could be stored until needed and then combined in fuel cells with oxygen from the air to generate electricity again.



Janos Marffy

INTO THE FUTURE

MEGAWATT MICROWAVES



▲ Giant orbiting spacecraft with solar panels will collect light and heat radiation from the Sun, convert it into powerful microwaves and beam it to Earth.

▲ Enormous receiving stations will convert this energy into electricity. Unlike sunlight, the microwaves will penetrate even the densest cloud cover.



▲ A fail-safe system will be essential as the intense microwave radiation could quickly reduce a major city to ashes if a fault caused a beam to be misdirected.

Alan Burrows



Francois Gohier/Ardea

REGIONS AT RISK

- Q VANISHING SPECIES
- Q GIANT DUST STORMS
- Q ACID FROM THE SKY

THREAT TO LIFE

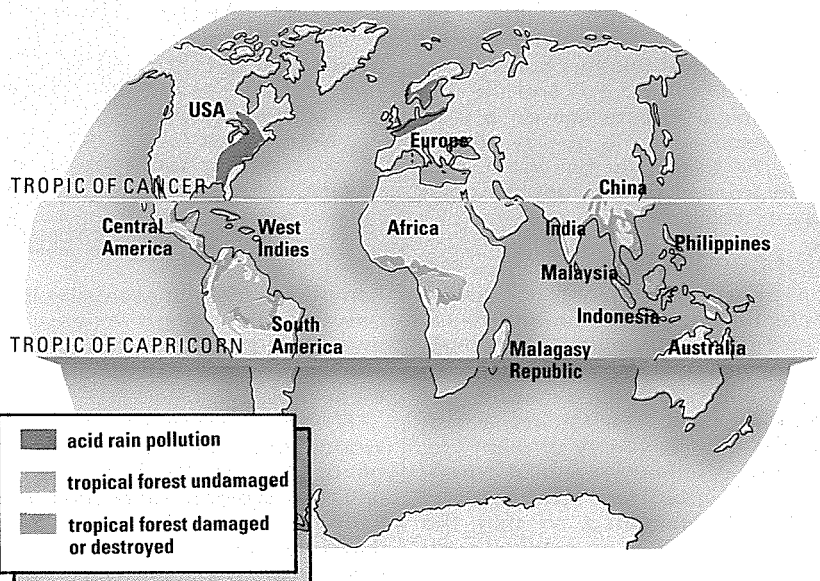
MAN SHARES THE PLANET
with about 40,000 species of
vertebrates – mammals, birds,
reptiles, amphibians and fishes
– and at least 250,000 plant
species.

Conservationists calculate that ten per cent of all plant species are at risk of extinction. There are also 1,000 animal forms on the endangered species list. Yet, this is just the tip of the iceberg. By far the most numerous of Earth's species are insects. Although they outnumber

the vertebrates by about 200 to one, untold numbers of insects are at risk. Pesticides are being sprayed on agricultural land, delicate environments are ploughed and bulldozed, and the massive rain forests of South America, Africa and South East Asia are being logged for timber, or cleared to make way for large-scale farms.

Between ten and twenty per cent of all living species may well have vanished by the end of the twentieth century. When the great dinosaurs and many marine creatures succumbed to extinction 65 million years ago, they disappeared at a rate of only one species every thousand years. Yet geologists refer to the period as 'the great dying'.

Every day, millions of trees are felled for timber, burned down or

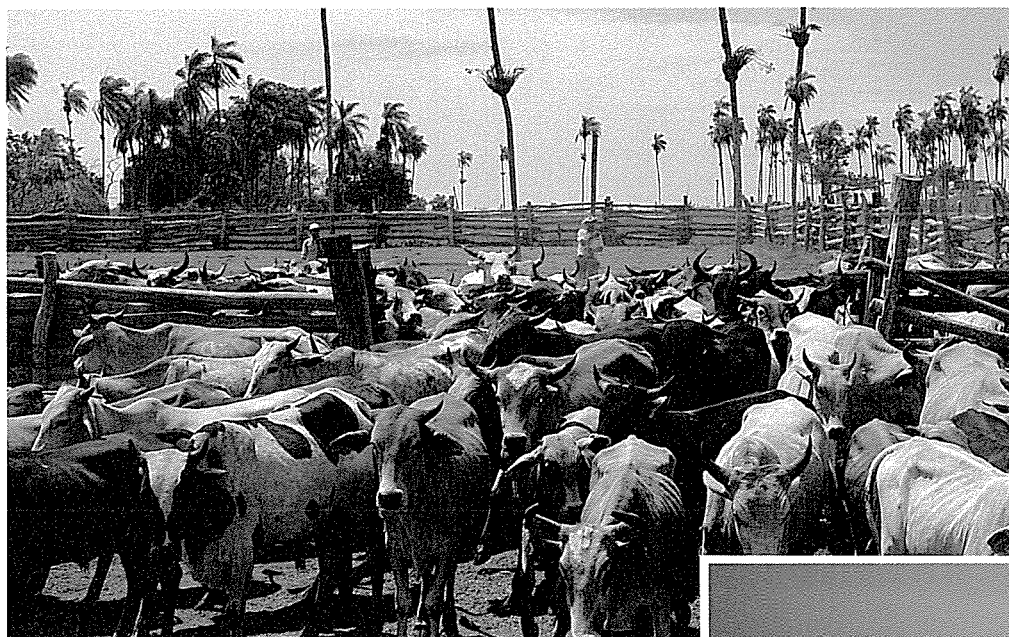


Janos Marffy

From the industrial regions in North America and Europe to the rain forests of Brazil, West Africa and the Pacific, Man's struggle for progress is having devastating side-effects that are endangering plant and animal life.

Acid rain, caused by fumes from factories and road vehicles, pollutes rivers, lakes, crops and natural vegetation. This problem is particularly severe in western Europe and down the eastern side of the United States.

The destruction of tropical rain forests means that many species of plants and animals will be lost forever. And, as forests absorb rainwater, their destruction often results in flooding. In India, for example, a 20 per cent loss of forests in recent years has doubled the land area liable to flooding. Already, almost 50 per cent of the world's tropical rain forests have been destroyed by man forever.



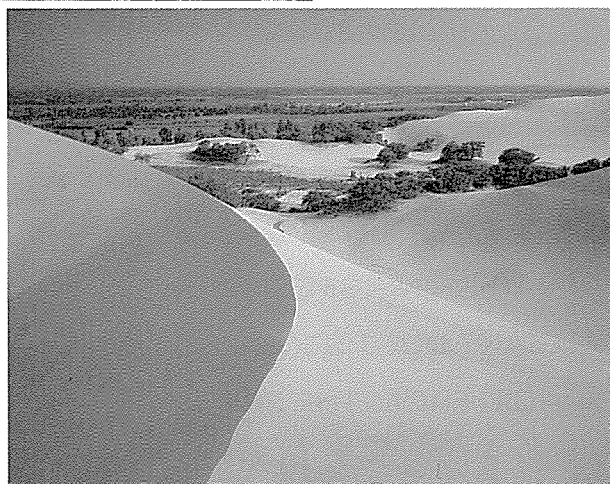
Beef production is an expanding business in South America, so huge areas of the tropical forest have been cleared to make room for cattle ranches. This destruction puts the people who live there at risk too. Some tribes have lived in the forests for thousands of years and have established highly specialized ways of life. They have learnt to hunt the creatures of the forest and to use plants for food and medicine. Ancient cultures are being lost as the inhabitants are forced to move out.

bulldozed by Man seeking land for farming. Each year sees an area equivalent to England and Wales razed to the ground. Already almost 50 per cent of the Earth's primal tropical forests have disappeared. Northern temperate forests can be reinstated, and this has happened to some extent in Europe and the US. But tropical forests live on a thin, fragile soil which is quickly eroded once the tree-cover has gone. And when tropical forests go, they disappear forever.

Food factors

The South American forest clearances have been carried out mainly in the interests of cattle ranching, which has grown enormously to satisfy North America's massive demand for beef. The forests, which contain a huge variety of plant life, much of it unknown and of potential use to Man for medicines and food, are decimated so that the burger-chains can be stocked with

Irrigation schemes can be used to recover vast areas of land that were once desert. However, we are still losing the battle, as much more land is being lost than reclaimed. About 230 million people are watching their land turn into desert. The rate of desert spread varies with the desert retreating in some areas.



Engelbert/Susan Griggs Agency

hamburger meat. It seems likely that powerful marketing forces will continue to increase the demand for hamburgers. So the outlook for these forests is bleak.

The industrialized countries of the world, accounting for about a quarter of the world's population, eat half the world's food production. Farm animals in the developed countries eat a quarter of the planet's grain in their feed — equivalent to the total human grain consumption of China and India together. It takes 16 kg of grain to produce just one kilogram of beef, and about eight kilograms of grain to produce one kilogram of pork.

Meat production is, therefore, an inefficient use of our food resources. In Third World countries, however, most of the grain produced is eaten directly — mainly in the form of bread and other flour-based foods.

Deadly harvests

Man has been creating deserts for a long time. The Fertile Crescent between Jordan and Iran was the birthplace of agriculture ten million years ago. Much of it is now barren desert, because the land was repeatedly sown and harvested without being sufficiently replenished. The lush farmlands of Mesopotamia



Paul Raymond

THE DEADLY SPRAY

Various forms of pollution, including the spray from aerosol cans powered by chemicals called chlorofluorocarbons (CFCs), are damaging the layer of ozone gas high in the Earth's atmosphere. This layer absorbs much of the Sun's harmful ultraviolet radiation. Without this protection, plants would die, and humans would become liable to suffer from skin cancer. Even a one per cent reduction in the amount of ozone in the atmosphere would have a serious effect on human health.



Sinclair Stammers

FLOODING



Camerapix Hutchison Library

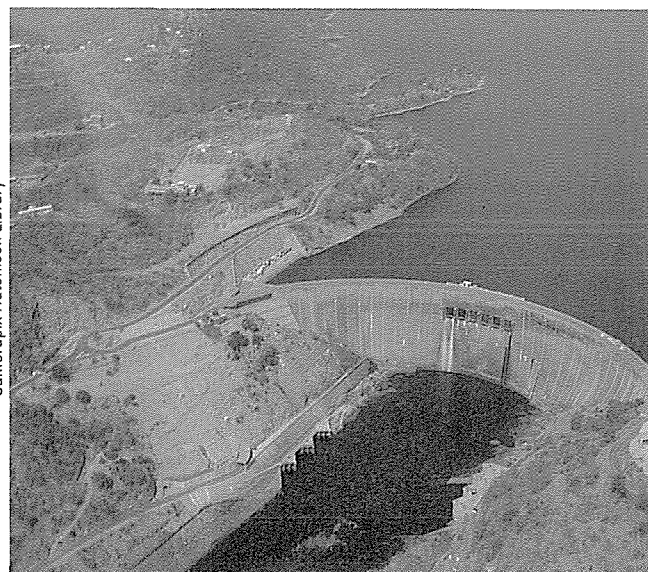
The destruction of tropical forests often results in flooding when the heavy rains come. In a forested area, the tree roots absorb rainwater from the soil. The water passes up the trees and is eventually released through the leaves as water vapour. In this way, much of the water that falls is recycled into the atmosphere. However, once the trees have gone, the water level can quickly rise when it rains, causing flooding. The rain also washes away the soil, later deposited as silt.

(situated where Iraq is today) were turned into desert by the very water that kept them green for so long.

Long-term irrigation often has the effect of saturating the ground with salts and minerals that are left behind when the water evaporates. Eventually the earth is so full of these imported substances that they kill anything planted in it.

In part, the increasing spread of deserts, particularly in Africa, may be due to modern Man's talent for polluting the air. The gases and emissions from vehicles and fac-

Damming a river can cause problems. The reservoir that forms may flood valuable farming land and wildlife habitats.



Gerald Cubitt/Bruce Coleman Ltd.

tories, and the residues released into the air by burning forest-land, increasingly prevent the sun's rays from bouncing back into space once they have hit Earth. Like greenhouse glass, they reflect the bounced radiation back to Earth, heating it a second time, and creating the so-called greenhouse effect.

In the course of the last hundred years, the Earth's temperature has gradually increased by up to 0.6 of a degree Centigrade. This temperature rise, although apparently small, drives rainfall north and south — away from the areas that need it most. Meanwhile, the deserts expand and as much as 200,000 square kilometres of potential farmland a year become impossible to use for agriculture.

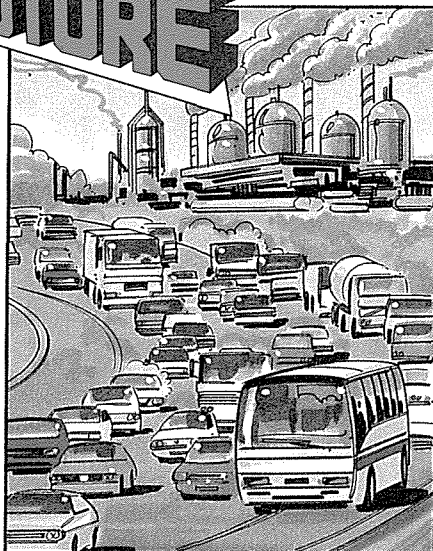
Man's abuse or neglect of the soil itself has ravaged a resource that

took centuries to build up naturally. Wherever trees are cut down, there is a danger of erosion as rains and frosts break down soil, to be carried away by storms and winds.

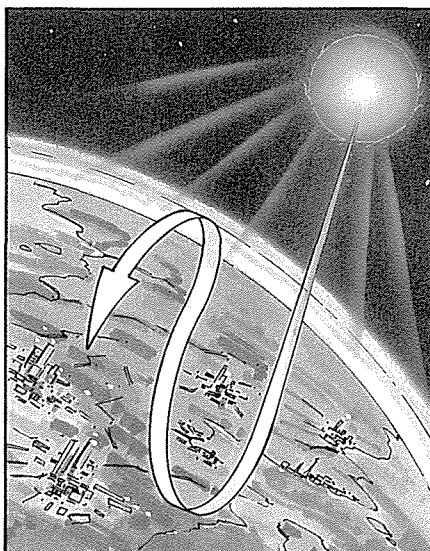
The rain forests are particularly vulnerable. Their soil tends to be very thin, and root systems are shallow. Clearing rain forests produces land that a single grass crop will exhaust. With little growing on it, the soil will eventually crumble and blow away in the wind.

The Great Dustbowl of the US stretches across five states — Kansas, Oklahoma, Texas, Colorado and New Mexico — and was once a centre of intensive farming. The land was farmed mercilessly, without any restitution in the form of fertilizers or animal manures. As a result, in the 1930s, over 350 million tonnes of topsoil blew away.

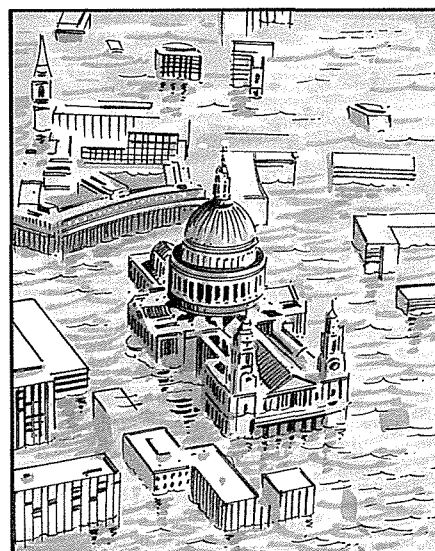
INTO THE FUTURE



▲ Fuels burnt in factories and road vehicles release carbon dioxide gas into the air, increasing the atmosphere's heat-trapping property — the greenhouse effect.



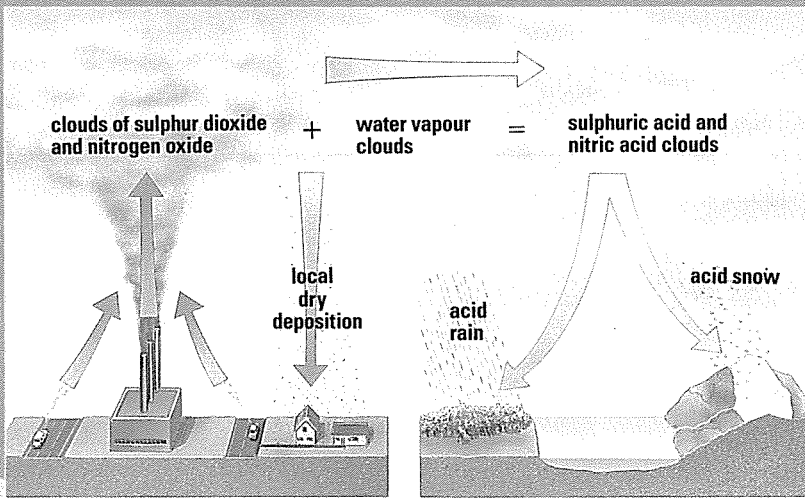
▲ Radiation from the sun passes through the carbon dioxide and warms the Earth. But the heat reflected back from the Earth is trapped around it.



▲ The gradual warming of the Earth could eventually melt the polar icecaps, causing the water level in the oceans to rise and swamp the world's lowlands.

Joe Lawrence

ACID RAIN

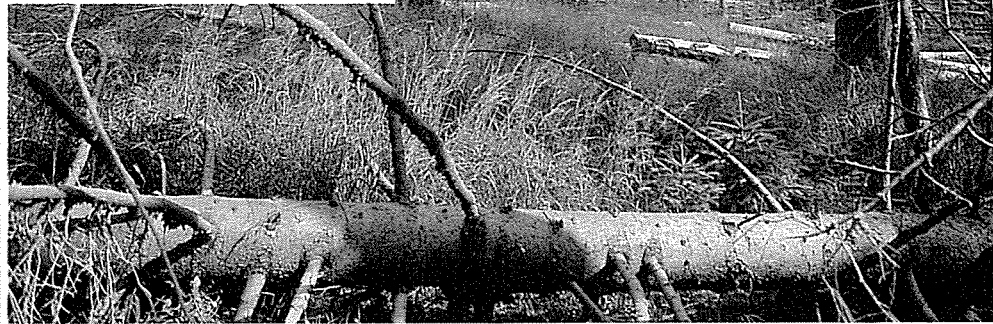


Acid rain pollution is an increasing problem in Western Europe. Large patches of forest have been destroyed, as the rain stripped the trees of their foliage.

Many of our industries pour sulphur dioxide and nitrogen oxide into the atmosphere. Nitrogen oxide is also released in the exhaust fumes of road vehicles. These gases together with smoke rise into the atmosphere. Some of the pollutants fall locally as dry deposition, which damages plants and affects human health. Pollution carried further into the atmosphere combines with moisture in the clouds to form clouds of dilute sulphuric and nitric acid. This eventually falls as acid rain or snow.

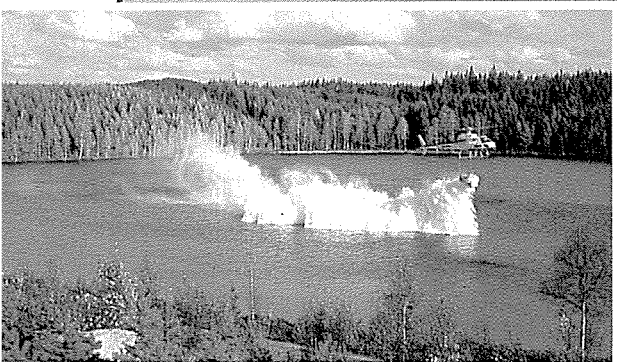
Wherever these pollutants fall, they kill plants and animals. Fish stocks are wiped out, and forests die back to brown skeletons. At first sight crystal-clear lakes in Scandinavia appear very beautiful. In fact they are so devoid of life – as a result of acid rain – that not even the murk of tiny plant cells cloud their waters. In the USA and Canada alone, 50,000 lakes may be biologically dead by the year 2000.

Polluted lakes that are too acidic for plants and animals can be partially restored. Lime is dropped into the water to neutralize the acid.



G.S.F. Picture Library

© Tore Hagman/Naturfotografen/N/Inset The Swedish Institute



Q AIR SPEED

Q REDUCING DRAG

Q WING SHAPES

Aviation Picture Library

WHY DOES IT GOES UP...

ALL MODERN AIRCRAFT work on the principle that air pressure drops as its speed increases — a fact first discovered in the 18th century by the Swiss doctor and mathematician Daniel Bernoulli.

To take advantage of this effect, an aircraft wing is curved on top so that, as the wing moves forward, the air above it has to travel further than the air below. As the air above the wing moves further in exactly the same time, the pressure above the wing is reduced. As a result, the excess pressure from below produces an upward force on the wing. This force — known as 'lift' — supports the aircraft as it flies.

If the angle at which the air

attacks the wing is increased, air flowing over the top must accelerate even more, and so the lift is stronger. However, if the angle is increased too much, air can no longer flow smoothly around the long path above the wing, and the aircraft will lose lift and go into a stall. On modern aircraft, the angle of attack is very small, usually not more than about two degrees in level flight.

Engineers have discovered that wings with a special cross-sectional shape, called an aerofoil, are the most efficient. When the aircraft is moving slowly, flaps on the trailing edges of the wings can

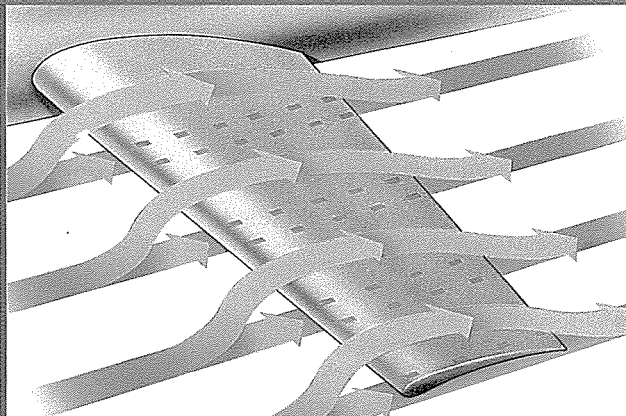
be lowered to make the wing more curved and increase the lift. This is done on take-off and landing.

Pitch, roll and yaw

Once it is in the air, the aircraft has to be capable of changing direction in three ways — pitch, roll and yaw. The pitch of an aircraft is governed by elevators on the tailplane. Moving these up or down causes the nose to rise or fall, so that the aircraft can climb or descend.

Ailerons at the rear outside edges of the wings are used to control roll. If one aileron is raised while the other is lowered, the lift generated by each wing will differ and the

AEROFOILS

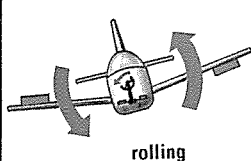
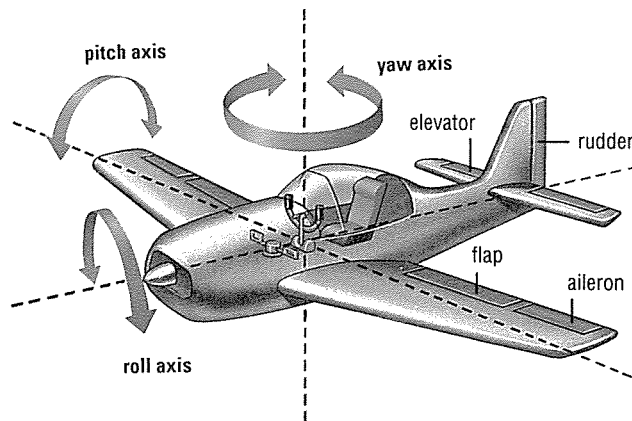


When a wing passes through the air, the airflow divides. Air flowing over the upper surface has farther to go than air flowing underneath, so an area of low pressure is formed over the top of the wing. This creates the lift, which cancels out the weight of the aeroplane.

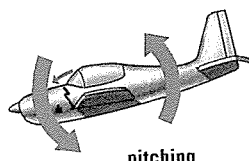
Mick Gillah

CONTROLLING AIRCRAFT MOVEMENT

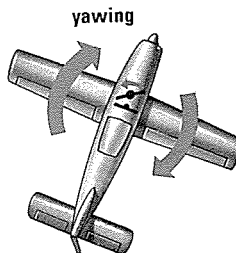
Pitch (up and down movement) is controlled by the elevators – hinged surfaces on the trailing edge of the tail-plane. Yaw (side-to-side movement) is achieved by moving the rudder – a flap on the tail fin. The ailerons, control surfaces on the wing tips, allow the aircraft to 'roll'.



rolling



pitching



yawing

Mick Gillah

aircraft will roll to the right or left.

If the pilot wants to turn to the right, he moves his control column to the right. This lowers the left-hand aileron and increases lift on the left-hand wing. Simultaneously, the right-hand aileron is raised and the lift on the right-hand wing is reduced. So the aircraft rolls to the right. Having rolled the aircraft in the required direction, the pilot then pitches the nose up slightly to avoid loss of height. The overall effect is that the aeroplane banks to the right.

The tail fin is fitted with a rudder, which is used to control yaw and keep the aircraft pointing in the right direction. But the aircraft is not turned using the rudder alone, as this would give insufficient control and would make the aircraft skid

On landing, the pilot fully extends flaps on the trailing edge of the wing and opens out the slots on the leading edge, or airbrakes, situated on top of the wings. This has the effect of increasing drag and lift so reducing the speed of the aircraft as it travels along the runway and preventing a stall.

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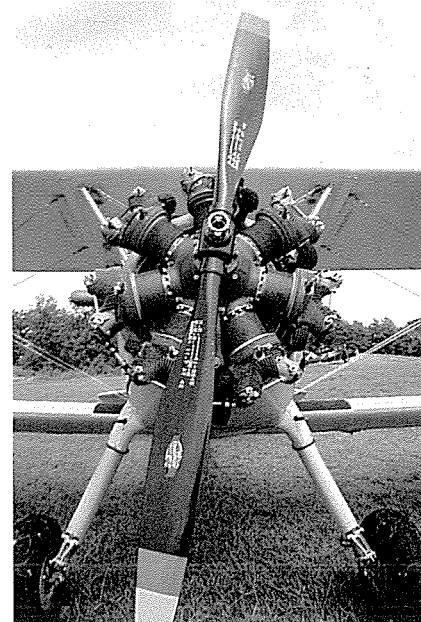


HEAVY AIR TRAFFIC

Heathrow, the largest of London's four airports, is also the world's main international airport. Heathrow currently handles more than 41 million passengers each year. Of these, over 34 million travel on international routes and over 7 million on domestic routes. More than 80 passenger airlines now use Heathrow, operating scheduled services to over 200 destinations throughout the world.

The airport has three runways and four passenger terminals, and a fifth terminal is planned in order to cope with the ever-increasing numbers of passengers and flights. Access to central London and main-line railway stations is provided by an underground rail link, but in order to deal with travellers more efficiently a new express rail link to Paddington main-line station is planned, which will take just 16 minutes to do the journey.

Fixed-pitch propellers are fitted to the smallest and simplest aircraft. Variable-pitch propellers are fitted to most propeller-driven aircraft, allowing the engines to run at their most efficient speed.



ZEFA

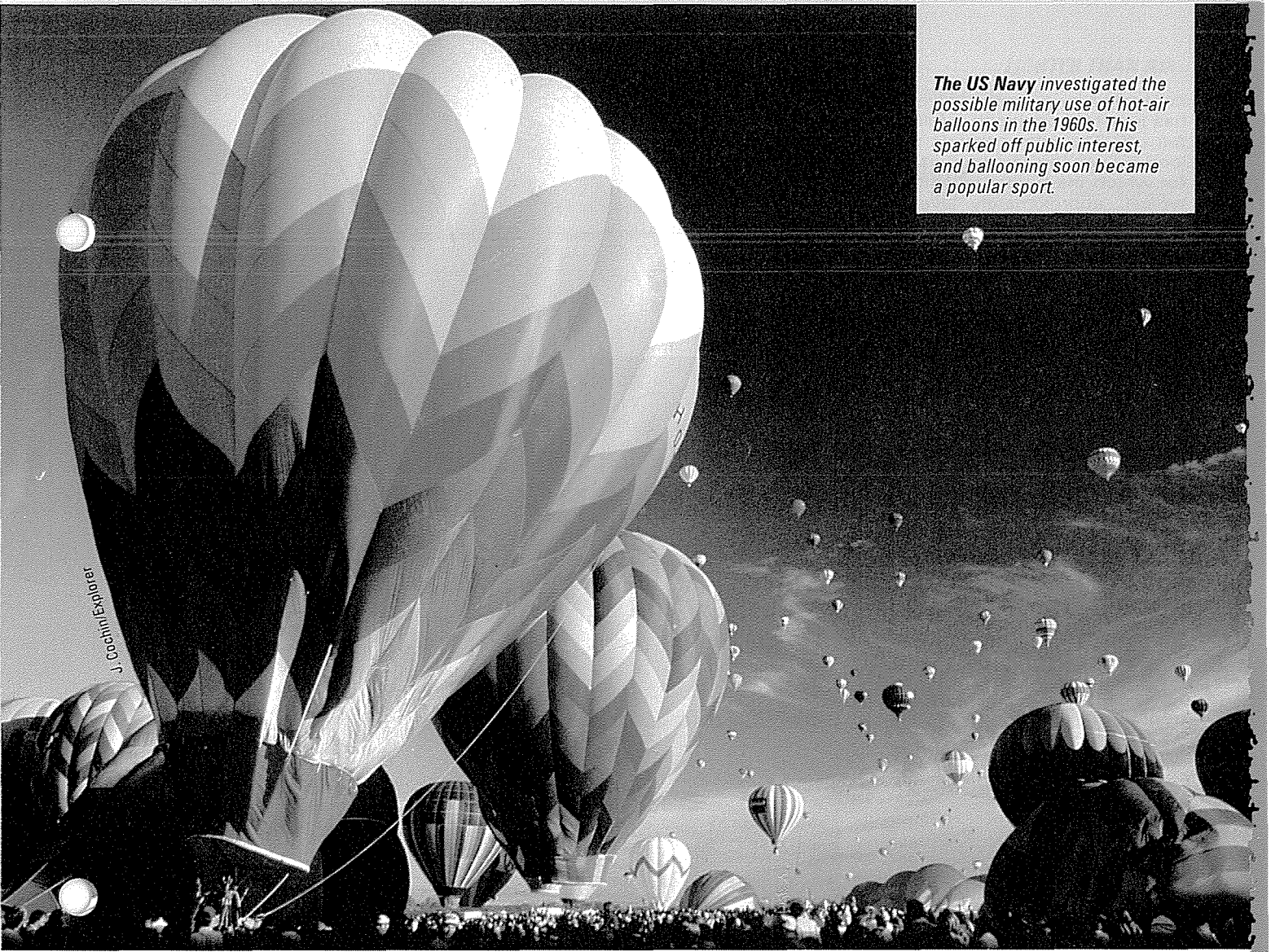
Just amazing!

FLYING FROGMAN

WHEN SCOOPING WATER OUT OF THE SEA TO COMBAT A FOREST FIRE, ONE PILOT

ACCIDENTALLY SCOOPED OUT A FROGMAN – HE WAS LATER FOUND IN THE DAMPENED FOREST.

Paul Raymond



The US Navy investigated the possible military use of hot-air balloons in the 1960s. This sparked off public interest, and ballooning soon became a popular sport.

 GETTING ALOFT

 HINDENBURG DISASTER

 HANG GLIDING

LIGHTER THAN AIR

BALLOONS AND AIRSHIPS have one thing in common – they can fly because they are lighter than air. Unlike fixed-wing aircraft, helicopters, birds and insects, they do not need to generate a force that is greater than their own weight.

Balloons can be separated into two categories – hot-air balloons and gas-filled balloons. Hot air is less dense than cold air, so when the air in a balloon is heated, the balloon will automatically rise. The two gases commonly used in balloons are hydrogen and helium, which are both less dense than air.

One major disadvantage of gas-filled balloons, however, is their cost. While air is free, hydrogen and helium must be specially manufac-

tured and are therefore expensive. Hydrogen is much cheaper than helium but it is also highly inflammable and extremely hazardous.

Hot-air balloons

A typical hot-air balloon has a volume of 2,180 cubic metres and contains 2.6 tonnes of air. The mass of the equipment and passengers is about 0.6 tonnes, so a little more than this mass of air must be driven out of the balloon to make it rise from the ground. This is achieved by heating the air to about 100°C, which is a typical flying temperature. The air expands as it is heated, forcing some of it out of the neck of the balloon.

Hot-air balloons are generally much bigger than gas-filled ones.

To achieve the same lift as the 2,180 cubic metre hot-air balloon, a helium-filled balloon need have a volume of only 580 cubic metres, and a hydrogen-filled balloon just 540 cubic metres.

The envelope – the part that contains the air itself – is generally made from nylon or polyester and is reinforced with strong webbing.

The air is heated by one or more large burners. Propane fuel is stored as a liquid in cylinders inside the passengers' basket, which is suspended from strong steel cables. The propane passes from the cylinders through a coiled tube at the base of the burners. This causes the fuel to vaporize and emerge in the flame as a gas.

The supply of fuel to the burner is

VIEW BALLOONS IN ACTION



Richard Cooke

Airships are now used for sight-seeing trips and for carrying advertising messages over major cities. Passenger services are planned to be introduced soon.

Weather balloons carry instruments that sense temperature and other atmospheric conditions. They can be tracked by radar while they are carried across the earth by winds at heights of over 24 km. These gas-filled balloons expand in the thinner upper atmosphere.



A. Guillou/Explorer

The highest trapeze act was performed by Ian Ashpole while hanging under a hot-air balloon (above) at a height of just over 5 km, in May 1986.



The Hot-Air Balloon Company Limited



Aviation Picture Library

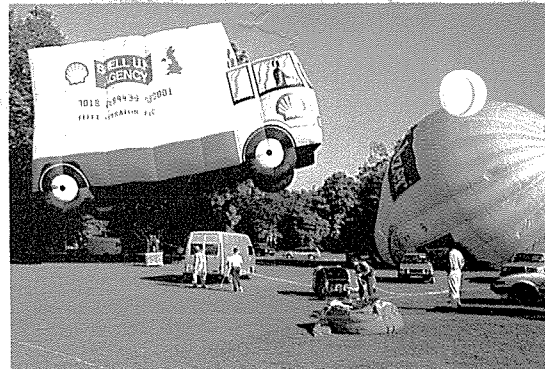
A world record was established in 1987 when 45 people flew together in the Cameron PH-EEN balloon, more commonly known as the 'Big 850'. The 24,000 cubic metre balloon was piloted on this epic 70 minute flight by its Dutch owner, Henk Brink.

Virgin Atlantic

Crossing the Atlantic in a hot-air balloon was a remarkable achievement by Per Lindstrand and Richard Branson in July 1987. The Virgin Atlantic Flyer (above) took just 29 hours and 23 minutes to reach Ireland from Maine in the USA.

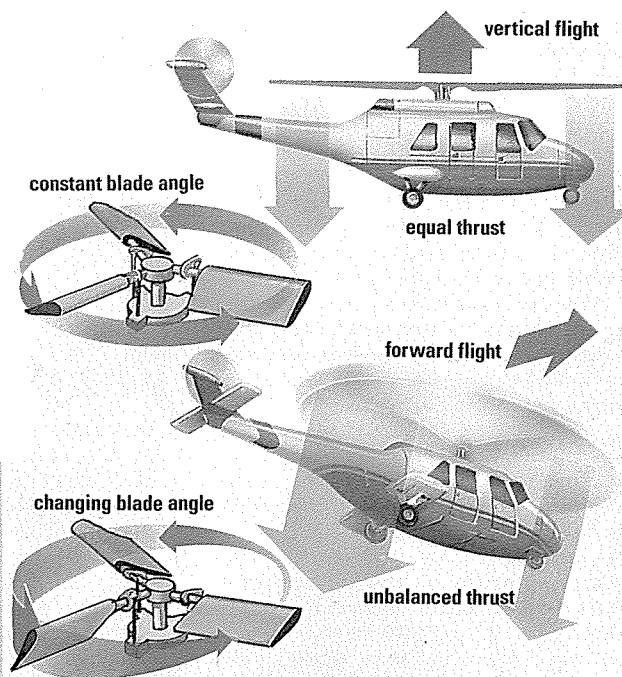


Amazing sights await visitors to a hot-air balloon rally. Balloons in the shape of a truck, building or bulbous bunny carry sight-seers aloft.



Hot-Air Balloon Co. Ltd

ROTOR FORCE



Mike Saunders

Helicopters fly according to the angle of the blades. At a constant angle, the blades push down equal amounts of air and the helicopter rises; when the angle is increased at the back, it creates a forward thrust.



Boeing/APL

AN AERIAL HOVERCRAFT, THE helicopter can take off and land vertically, and even stand still in mid-air. This gives it a great advantage over fixed-wing aircraft, for unlike them, the helicopter rises into the air and moves through it because of its rotor, or rotating blades.

When the helicopter rotor is turning, air passes over its 'wings' and the helicopter can generate enough lift to take off vertically. But to do this, it requires three to ten times the power needed by a typical aeroplane.

Helicopters are extremely difficult to fly, requiring great co-ordination

between hands and feet. The left hand operates the collective lever. This changes the pitch of all the blades by the same amount. An increase in pitch results in increased lift. Decreasing the lift makes the helicopter hover or descend.

Helicopter control

The right hand controls the cycle stick. This regulates the horizontal motion through the air. To make the helicopter move forward, the rotor is tilted forward slightly, and to go backwards, the rotor is tilted in the opposite direction. Left and right turns are made by tilting the rotor sideways.

***Boeing CH-47D Chinooks** are used by the US Army to transport its 2,268 kg trucks. Dual point suspension stabilizes the load and permits faster cruise speeds.*

The feet operate pedals that control the tail rotor. This is a compensating rotor, usually smaller, that balances the twisting tendency produced by the main rotor turning in one direction.

Some helicopters, like the Boeing CH-47D Chinook, have two main rotors that rotate in opposite directions. The movement of one cancels out the other, so twin rotor helicopters do not need tail rotors.

Its ability to take-off and land vertically makes the helicopter ideal for use in difficult terrain, where they have to get in and out without long runways.

In city centres, where space is at a premium, helicopters are playing an increasing role in getting passengers in and out of built-up areas. Most lighthouses are now fitted with helicopter landing pads and so are oil rigs around the world.

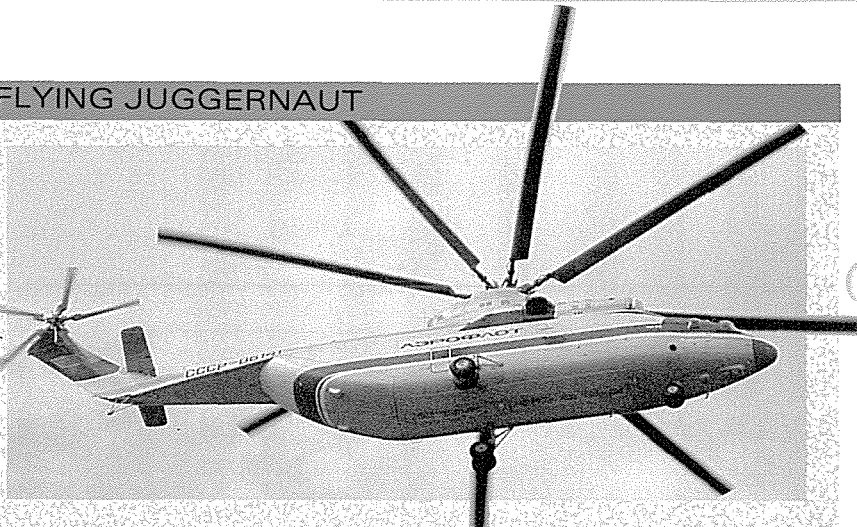
Helicopters are also used by the armed forces to transport men and machines, or as ground-attack aircraft. The helicopter provides a very stable weapons platform.

New hybrid

Electronic systems, including auto pilot, and new, lighter materials continuously contribute to more efficient helicopter design. But the inherent nature of the helicopter's flight means that it cannot fly much faster than about 380 km/h. This is because, beyond that speed, no more lift can be achieved by the retreating blades – whatever the angle of the pitch – while the

FLYING JUGGERNAUT

Aviation Picture Library



The largest helicopter in the world is the Soviet-built Mil Mi-26 Halo. The Mi-26 first flew in 1977, made its debut with the military in 1983, and was fully operational two years later.

The Halo has eight blades on its main rotor, which measures 32 metres in diameter, and is powered by two Lotarev D-136 engines, which can each produce 16,760 kW of power.

The fuselage is 33.7 metres long which is comparable with that of a

C-130 Hercules. The Mi-26 weighs 28 tonnes and can normally lift a payload of 20 tonnes. In 1982, at Podmoscovoie in the then Soviet Union, an Mi-26 lifted a total mass of 56.77 tonnes to a height of 2,000 metres, setting a new world record.

The Mi-26 carries a crew of five, has a range of 800 km and can fly at a maximum speed of 295 km/h. More than 50 have been built, and it is still in production.

advancing blades tilt the helicopter uncontrollably to the left.

The solution lies in a hybrid between a fixed wing and a rotor aircraft, such as the tilt-rotor Osprey and the part-chopper, part-jet, X-wing.

For landing and take-off, the Osprey hovers like a helicopter, but once in the air, the engine housing and rotors tilt forward 90 degrees to become an aeroplane. The X-wing, too, takes off and lands vertically using its rotors, but in flight, the rotor becomes stationary.

Aviation Picture Library



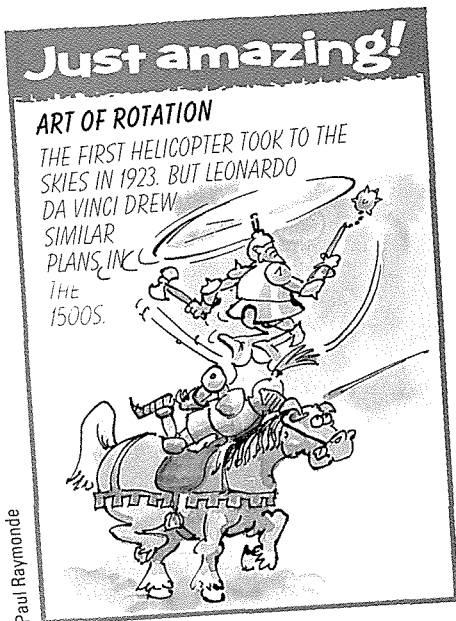
McDonnell Douglas Corporation



The Soviet Mil Mi-24

Hind helicopter can carry air-to-ground and air-to-air missiles. The Hind A, B and C are assault helicopters. The Hind D, E and F are used in anti-tank operations. Hind helicopters were used extensively in Afghanistan during the Soviet occupation in the 1980s.

Future fighters, such as the LHX, designed by McDonnell Douglas and Bell, will fulfill the US Army's requirement for high-technology, agile, multirole helicopters that can be used for combat and reconnaissance.



Paul Raymond

CHAIN REACTION

Earth Satellite Corporation/SPL

Satellite photographs showing different surface rocks in false colours help geologists to find uranium deposits.

AT THE CENTRE OF ATOMS IS the source of the devastating power behind Man's most destructive weapons – nuclear bombs. And yet atoms are extremely small. A row of ten million atoms would measure only one millimetre from end to end.

All matter, whether solid, liquid or gas, living or non-living, is made up of these tiny particles. And each atom consists of even smaller particles called neutrons, protons and electrons. The protons and neutrons are bunched together to form the central core, or nucleus, of the atom, with the electrons (which are very much smaller) spinning around it like planets going around the sun.

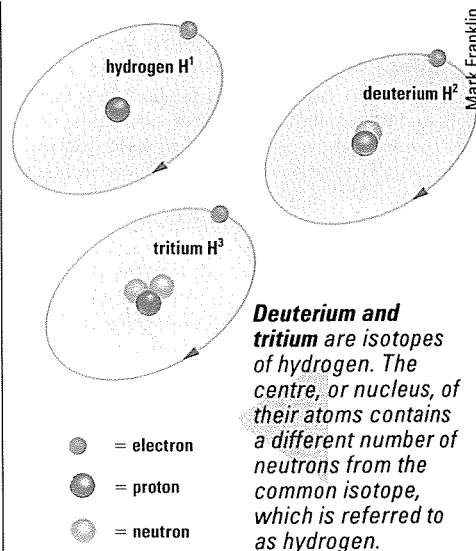
What makes an atom of one element different from that of another is the number of protons and neutrons in its nucleus. For example, the nucleus of a hydrogen atom is just a single proton, while the nucleus of a carbon atom has six protons and six neutrons. Uranium atoms are far bigger and heavier.

The most common type of uranium is uranium-238 (U-238). Its

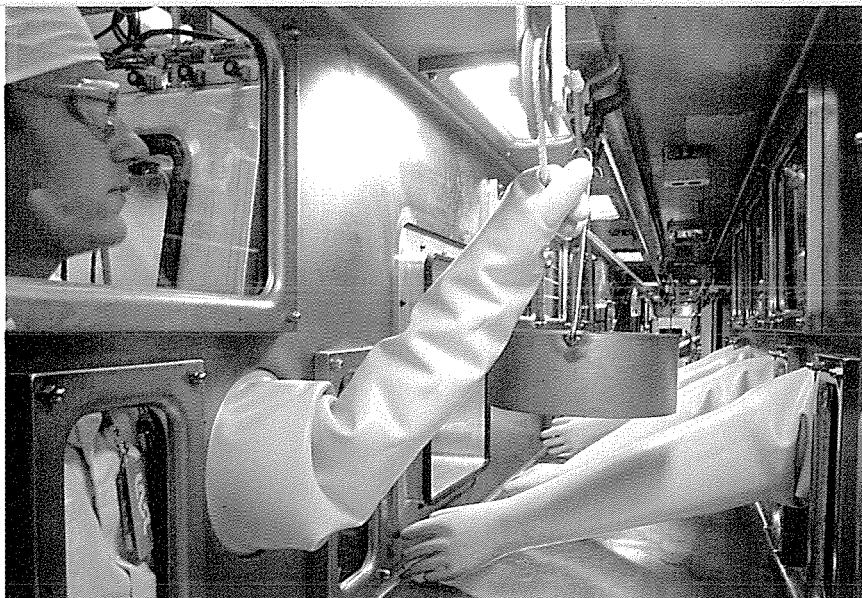
Mining uranium in Ontario, Canada. The rocks are dug out, crushed, and then treated with chemicals to produce 'yellow cake'. This oxide contains about 85% of uranium by weight.

nucleus has 238 particles: 92 protons and 146 neutrons. About 99.3 per cent of natural uranium is U-238. The other 0.7 per cent is mainly uranium-235 (U-235), which has the same number of protons, but three fewer neutrons in its nucleus. These different forms of the same element are called isotopes.

Because uranium atoms are so big, the atomic forces binding the protons and neutrons within each nucleus can only just hold the whole thing together. The atoms



Mark Franklin



Fatal cancer is the likely outcome of inhaling just one thousandth of a gram of plutonium. To protect workers, plutonium is handled on glovebox conveyors.

are liable to break up, and the reactions that occur when this happens release vast amounts of energy.

Splitting the atom

In any piece of uranium, there will always be a few atoms that become unstable and break up, scattering their protons and neutrons. Some of these will recombine, forming the smaller atoms of lighter elements, such as krypton or barium.

Any spare neutrons will usually fly straight out of the uranium through spaces between the atoms. But some neutrons collide with the atoms. If a neutron hits a U-238 atom, it will either bounce off it or, if it is going slowly enough, it will be absorbed by the atom.

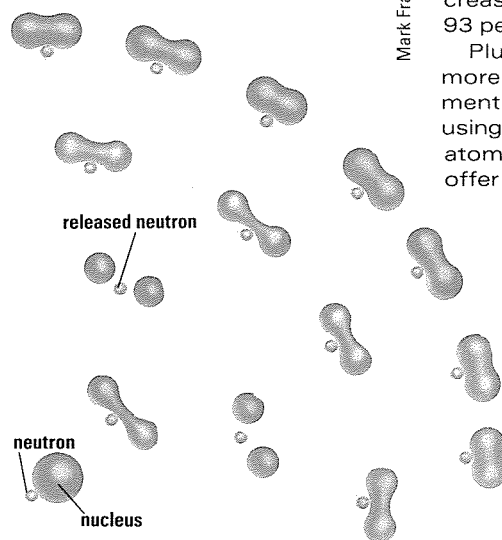
But if a neutron crashes into a U-235 atom, it will split the atom in two. This splitting, called nuclear fission, releases energy from within the nucleus — along with two or three spare neutrons, which can go on to split yet more U-235 atoms.

Nuclear weapons

If the piece of uranium is big enough, and contains a high enough percentage of U-235 atoms among the U-238, the chances of a spare neutron hitting and splitting a U-235 atom are much increased. And, if the conditions are right, this fission process will continue until all the U-235 atoms have been split up.

This sequence of neutrons splitting atoms, producing more neutrons, which split even more atoms, is called a chain reaction. During a chain reaction, a huge amount of energy is released from within the atoms.

In a nuclear power station, the reaction is carefully controlled. It spreads very slowly, and the heat energy it releases is used to boil water and produce steam. This



Mark Franklin

drives turbines linked to generators to produce electricity. In an atomic bomb, however, a chain reaction takes place almost instantaneously, and the energy released creates a massive blast.

The hydrogen bomb is even more powerful. It uses the heat from an atomic bomb to set off a fusion reaction. Two isotopes of hydrogen, called deuterium and tritium, fuse (join) together with the sudden release of an enormous amount of energy.

In order for a fission reaction to take place, the uranium used must contain a higher proportion of U-235 than the 0.7 per cent naturally present in it. So, before it can be used, the uranium must be enriched to increase its U-235 content — to at least 90 per cent for bombs and about 2 to 4 per cent for reactors.

Uranium enrichment

Because the technology needed to enrich uranium reactor fuel can also be used to make highly enriched uranium for atomic bombs — weapons-grade uranium — the countries that have the technology try to keep the details of it very secret. Many countries now have nuclear power stations, but most of

them have to buy their enriched reactor fuel from nations with enrichment plants. However, an increasing number of countries have managed to build their own enrichment plants, and this gives them the ability to make atomic bombs. These countries include the UK, USA, Russia, France and possibly India, Pakistan, South Africa, Israel, Argentina, Iran and Iraq.

Plutonium production

Plutonium can also be used both as a reactor fuel and for making bombs. Only minute amounts of plutonium occur in nature. When the uranium-238 in a nuclear reactor absorbs neutrons, it changes into plutonium (Pu). For weapons, this plutonium must be enriched to increase its Pu-239 content to at least 93 per cent.

Plutonium enrichment is even more difficult than uranium enrichment. But new techniques, such as using laser beams to separate Pu-239 atoms from vaporized plutonium, offer a relatively quick and cheap

A chain reaction starts when a free neutron splits the nucleus of an atom, such as uranium-235. In the process, more neutrons are released, and these split more of the uranium atoms. The reaction continues in this way, releasing large amounts of energy in the process.

THE ULTIMATE TEST

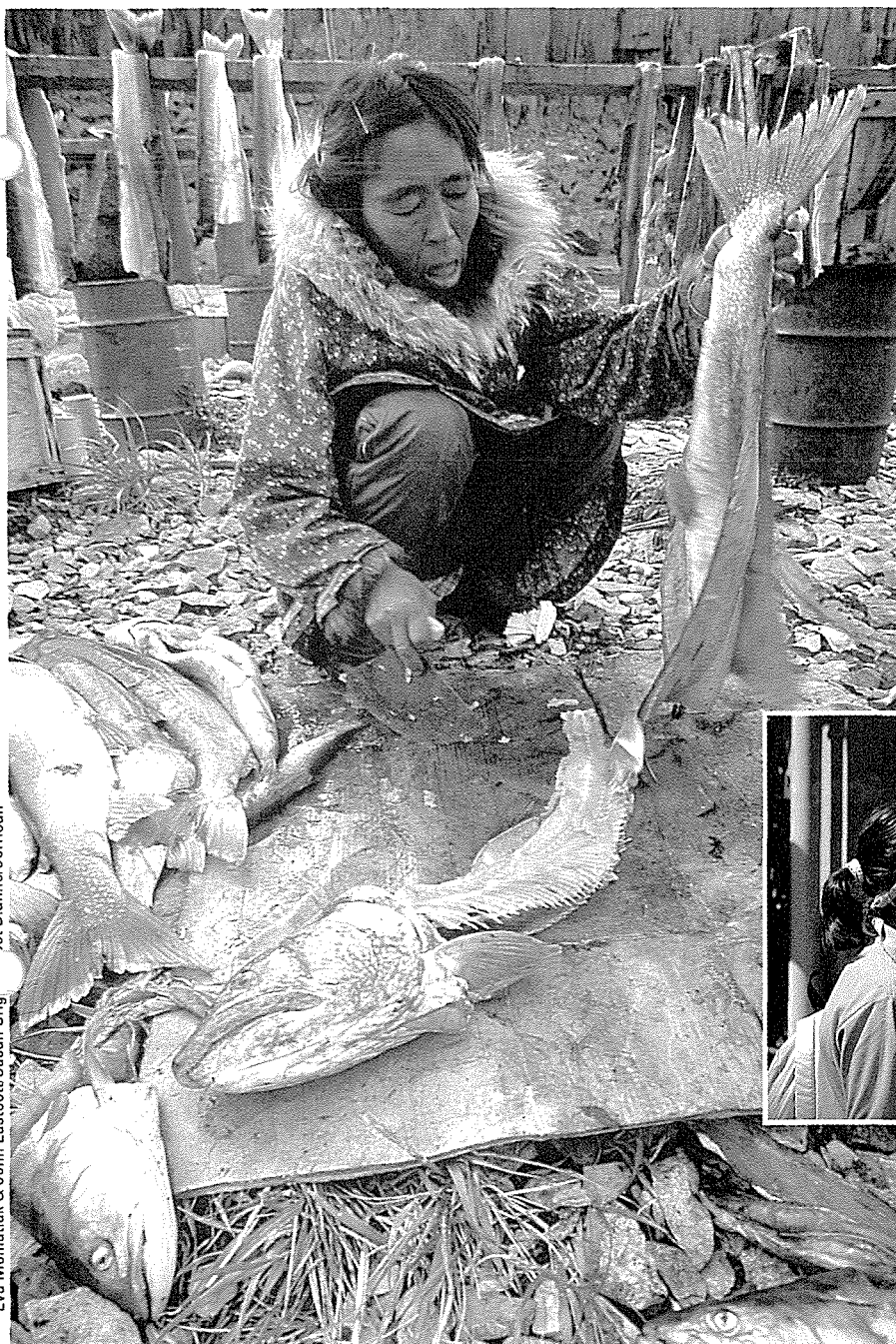


A collision between a 160 km/h train and an empty nuclear fuel transport flask was staged to demonstrate that moving radioactive materials by rail was perfectly safe. This followed the expression of fears by people living near the railway routes concerned. After the crash, the flask was intact.

CEGB

way of making weapons-grade plutonium from reactor waste. This may lead to an alarming growth in the number of countries producing nuclear weapons and an increasing danger of nuclear war. There would also be a greater risk of nuclear weapons getting into the hands of terrorists.

FUEL FOR LIFE



Fast food, though colourful and attractive, makes a poor substitute for proper meals.

Fish keeps an Eskimo fit. Essential fatty acids from fish oils combat the high dosage of animal fat in an Eskimo's diet.

WHEN THE AUSTRALIAN Aborigine eats a tasty grub and the Masai warrior drinks warm blood from a cut in the neck of a cow, they are both taking in vital nutrients.

Despite their great variety of diets, all human beings require the same nutritional elements. These are proteins, fats, carbohydrates, vitamins, minerals, fibre and water.

Proteins

About 18 per cent of human body-weight consists of proteins. These are very complex structures made up of chains of building blocks called amino-acids. There are at least 22 amino-acids. They combine in varying ways to form the different proteins.

The proteins found in meat, fish, milk and eggs have all the essential

amino-acids and are said to be of High Biological Value (HBV). The proteins found in vegetables, nuts and grains lack one or more of the essential amino-acids and are considered of Low Biological Value (LBV), except for soya bean which has HBV protein.

However, this does not mean that LBV proteins are inferior. They can be combined with HBV proteins or different LBV proteins can be combined, such as beans with grains, to provide the essential amino-acids.

The body needs protein in order to grow, so it is particularly important for children. Protein also helps the body repair damaged tissue. In most societies, proteins, such as meat, fish, cheese and eggs, are the most expensive form of basic food. However, beans, peas, lentils, whole cereal grains and nuts are

also an important source of proteins, especially for vegetarians.

Nutritionists recommend that an adult eats about 0.7 gm of protein per kg of bodyweight every day. Children need about twice this proportion, and pregnant women need slightly more than this average requirement, so that the foetus can grow satisfactorily.

In famine areas, a lack of proper dietary protein often results in 'kwashiorkor', a dietary deficiency disease affecting children. Their growth is stunted, they are anaemic and their livers deteriorate. Milk can cure it, but all too often, kwashiorkor results in death.

Fats

Food fats, which can be solid or liquid, are obtained directly from meat, fish, nuts, seeds and some

A B C OF VITAMINS – FOODS THAT SUPPLY THEM AND WHAT THEY DO

VITAMIN	The B Complex								
	A Retinol	D Cholecalciferol	E	K	B1 Thiamine	B2 Riboflavin	Nicotinic acid	B12 Cobalamin	C Ascorbic acid
Function	Helps form visual purple in retina to help see in dark Keeps mucous membranes moist and infection free Maintains healthy skin Promotes growth in children	Helps absorb calcium and phosphorus which are required for bone and teeth formation	An anti-oxidant. It protects against the accumulation of biological toxins.	Helps produce coagulants in blood for clotting	Helps release energy from carbohydrates Promotes growth in children Maintains healthy nerves	Promotes normal growth Helps release energy by oxidation of amino-acids and fats	Helps release energy by oxidation, especially of carbohydrates	Required for metabolism of amino-acids and enzymes in body	Helps make connective tissue which holds cells together Helps absorb iron Helps strengthen bones and teeth Helps build and maintain skin and lining of digestive passage
Found in	(As retinol:) Milk, cheese, egg yolk, butter, oily fish, fish liver oil (As carotene:) Carrots, spinach, watercress, prunes, cabbage, tomatoes, apricots, parsley	Liver, fish liver oils, oily fish, egg yolk, milk and its products, margarine, sunlight	Lettuce, seeds, peanuts, wheat-germ oil, grasses, milk and milk products, egg yolk	Leafy vegetables and in the intestine	Cereals, yeast, all meat, eggs, fish roe and milk				Rosehips, blackcurrants, green peppers, oranges, grapefruits, lemon, strawberries, cabbage, spinach, broccoli, Brussel sprouts, potatoes
Deficiency diseases	Night blindness Drying out of skin and mucous membranes Children's growth retarded	Rickets in children, Osteomalacia in adults Children's growth retarded	Anaemia, nervous disorders, muscle weakness	Deficiency disease is rare	Depression, loss of memory and concentration Children's growth retarded Neuritis Beri beri	Lack of growth Dermatitis and conjunctivitis Swollen tongue, sore mouth	Dermatitis Dementia Diarrhoea	Anaemia with enlarged red blood cells	Loss of connective tissue Broken blood vessels Painful joints and muscles Bleeding gums, loose teeth Scurvy
FAT SOLUBLE					WATER SOLUBLE				

Paddy fields are a common sight in South East Asia where rice forms the staple diet.



Wheat forms the staple in more temperate climes where it is used chiefly in bread.

vegetables. Fats are made up of a combination of glycerol and fatty acids, the basic components of which are hydrogen, oxygen and carbon. There are at least 40 fatty acids and, depending on how their carbon and oxygen atoms are arranged, they are classed as saturated or unsaturated fatty acids.

Unsaturated fatty acids are found mostly in oil extracted from vegetables, nuts and fish livers, or in fatty

fish. Fats which are solid at room temperature, such as lard, are high in saturated fatty acids. Eating too many saturated fatty acids increases the cholesterol level in blood, which can lead to heart disease. But 'sea-food' fatty acids, found in fish oils, lower blood-cholesterol levels.

Fats are important to cell structure. Because they are also much more efficient, weight for weight,

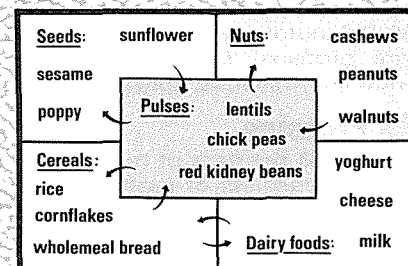
than protein or carbohydrate in storing energy for future use, any excess is retained by the body, literally, as fat.

Most fruits and vegetables contain less than one per cent fat; red meat is generally 30 per cent fat and 15 per cent protein, though pale meats, such as rabbit and chicken, are lower in fat. The white of an egg has only a trace of fat, while the yolk is about 30 per cent fat. This is why body-builders and weight-lifters will consume as many as two dozen egg-whites at one go, to obtain the high protein content – half that of beef – without the high fat content of the yolks.

Carbohydrates

Carbohydrates are the major source of energy. They, too, are made up of carbon, oxygen and hydrogen atoms. Starchy carbohydrates are

MEATLESS PROTEINS



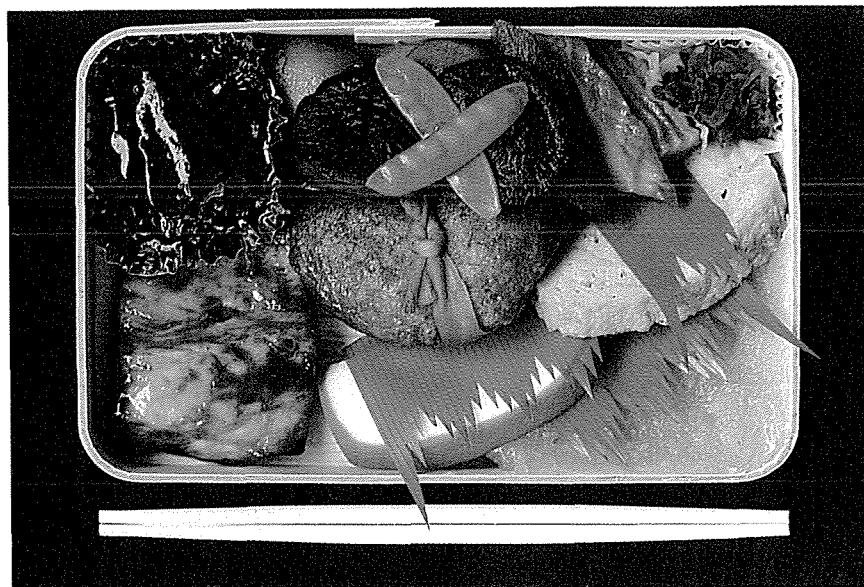
Meatless proteins are best eaten in combination (as above) to give a full complement of amino acids.

found in rice, wheat and other cereals, as well as pasta and potatoes. Sugary carbohydrates are found in honey, syrups and in both refined and unrefined sugar.

In the body, carbohydrates are quickly and easily converted into glucose which is used to provide energy. A small portion of glucose is stored in muscles as glycogen. A man weighing 70 kg has about 368 gm of stored glycogen.

Unrefined starchy carbohydrates and fruits are a good source of fibre

Japanese meals, designed to please the eye and the palate, are made up of nutritious elements, such as mineral-rich seaweed.



Telegraph Colour Library



The milk round in Georgia, Eastern Europe draws all generations. The natives here boast very long lives, thanks partly to milk-derived products, such as yoghurt. Milk, an almost complete food, forms the diet of babies until they are weaned.

certain functions and to form a part of body fluids.

Some minerals, such as calcium, iron, phosphorus, potassium, sulphur and magnesium are required in larger quantities than iodine, copper, manganese, fluoride, cobalt, nickel, zinc and chromium – these are needed in tiny quantities and so are known as trace elements.

Water, too, is a vital element necessary for the upkeep of the human body; in fact, 70 per cent of the body is made up of water. It is an essential ingredient of all body fluids, such as blood, urine, saliva and sweat. It keeps the mucous membranes, bronchial tubes and the digestive system moist and also helps lubricate the joints.

Most foods contain water, especially fruits and vegetables. A minimum of two or three litres is a recommended daily intake.

which is essential for digestion. Lack of fibre is linked with certain cancers.

Vitamins

Another group of vital nutrients supplied by food is vitamins. They are necessary only in small quantities and most of them cannot be made in the body but have to be found in the diet.

Vitamins are water-soluble or fat-soluble. They are popularly known

by letters, but they also have their own names. Vitamins A, D, E and K are fat-soluble, while vitamins C and the B-complex are water-soluble.

Minerals and water

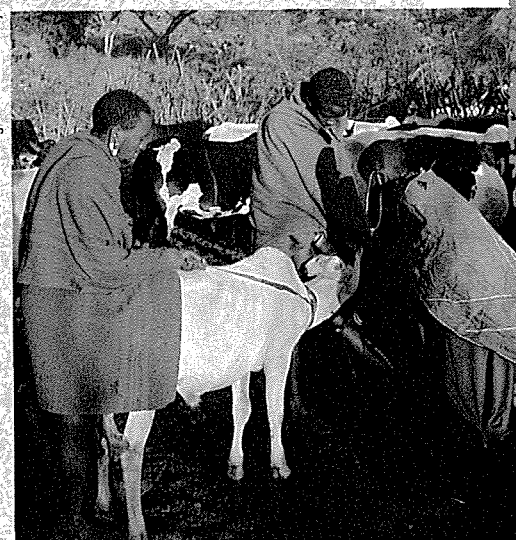
Apart from the vitamins, minute quantities of a range of minerals are required to build the body, control

CUSTOM AND PRACTICE

There is little that grows on our planet that someone will not eat – and much that many won't. Geography, culture and religion are only some of the factors that determine the great variety of diets worldwide. But in spite of the diverse ingredients used, humans have developed well-balanced diets to suit their circumstances.

The sinuous Masai of East Africa are herdsmen, counting their wealth in cattle which they rarely slaughter. But they regularly collect and drink their animals' blood to supplement their simple diet of fruit, milk and small quantities of meat.

Some religions, such as certain forms of Hinduism and Buddhism, advocate vegetarianism. Vegans (very strict vegetarians) do not eat eggs or dairy products – only plant foods such as cereals, pulses and seeds, as well as fruit and vegetables. Orthodox Muslims and Jews do not eat pork and only eat other prescribed meats that come from



ritually slaughtered animals. Orthodox Jews do not eat shellfish and do not mix milk and meat.

Just amazing!

FIRST, FIND AN EGG...

FOR SPECIAL FEASTS, BEDOUINS WILL PREPARE A ROAST CAMEL, WHICH IS STUFFED WITH A SHEEP, WHICH IS STUFFED WITH A WHOLE CHICKEN, WHICH, IN TURN, IS STUFFED WITH FISH, WHICH IS ULTIMATELY STUFFED WITH EGGS.



Robert Harding Picture Library

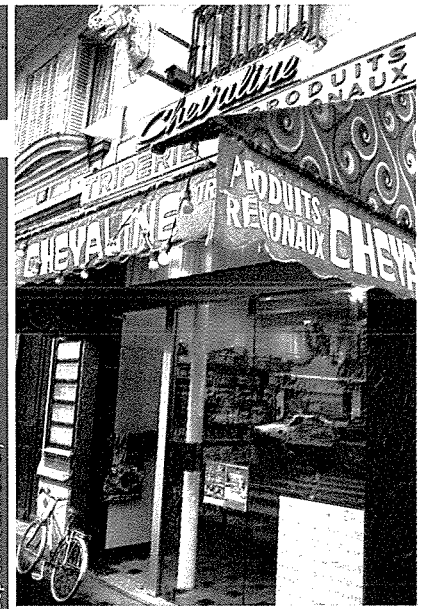
Keith Scholay/Planet Earth Pictures



One man's vermin is another's appetizer. Freshly caught bats are considered good to eat in Indonesia where they are sold by the roadside.

They eat horses in France and Belgium — and so would the rest of Europe were it not for an 8th-century ban by Pope Gregory III to differentiate between newly-converted Christians and horse-eating pagans.

Cephas Picture Library



Coming out of their shells to make an edible snail dish is the supply of a favorite French dish. Some are sold ready-filled with garlic butter (below). The French eat 40,000 tonnes a year, but only farm a fifth of the snail farms from across the world, including Britain, supply the rest.

Jeremy Thomas/Biobios



Cephas Picture Library

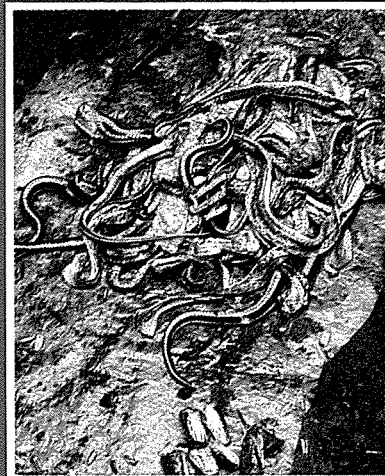


Image Bank

Char-broiled locusts are a Burmese delicacy. Entomophagy — eating insects — is common in many parts of the world. Insects provide protein and vitamins.



Heather Angel



Fillet snake on sale in a Shanghai market. Some animals are eaten for a belief in their powers — in China, snakes are thought to be an aphrodisiac.

Pussy in the pot is how this cat in a Chinese market will end up. Dogs are also bred and sold for food since no social taboo exists on eating animals that would be cherished as pets in other countries.

Heather Angel



Peter Stephenson/Planet Earth Pictures

A camel has many uses. In the desert, where water can be scarce, it can be used to the end, providing animal protein for the Arabian diet.

TIPPING THE BALANCE

- Q FOOD ABUSE
- Q ADDITIVES
- Q IMBALANCES



Rex Features



Weighing over 500 kg, New York's fattest resident Walter Hudson has been unable to leave his bedroom for over 17 years. When he attempted to leave his house, he got stuck in the doorway. After that, he went on a diet of just 1,900 calories a day.

Half the world's population is under-nourished. By the year 2000, Africa, Asia and South America will need to provide double the amount of food they produce today, simply to maintain the present daily intake of their ever growing populations.

IN 1980, 12 MILLION CHILDREN died of protein deficiency worldwide. The figures of famine make depressing reading. Yet on the other side of the coin affluent citizens of advanced countries are dying from obesity diseases.

Each year over half a million Americans and 180,000 Britons die from coronary artery disease, brought on by the build up of cholesterol and other fatty substances in their blood vessels. The average person in the western world consumes between 400 and 700 milligrams of cholesterol a day. The American Heart Association recommends a limit of no more than 300 milligrams a day. That is just 25 milligrams more than is contained in a medium-sized egg yolk.

Obesity through over-eating,

especially of unhealthy foods, is associated with a large number of life-threatening conditions, including diabetes, high blood pressure, damage to vital organs and cancer. So while people in developed countries die of excessive amounts of food, others die of starvation.

● Abuse of resources

The imbalance of world production and consumption often results in livestock being fed foodstuffs which could save the lives of large numbers of undernourished humans. Artificially high rice prices in the 1970s resulted in hundreds of thousands of deaths in Bangladesh. An increase in the demand for beef elsewhere in the world, coupled with poor maize and soya crops, caused western farmers to feed

their herds with skimmed milk and wheat, while skimmed milk imports into under-developed countries suffering from famine were lacking.

Another misuse of protein sources can be seen in the fishing industry, where shoals of fish such as herring and mackerel have been decimated by ultra-modern fishing methods. In the past, fish were often processed into fish meals and added to livestock feeds – a process that has led to many intensively farmed chickens tasting fishy. In some cases the chickens have even been injected with chicken flavour to mask the fishy taste.

● Problems of excess

A further example of imbalance is the problems faced in cultivating enough food in developing coun-



tries to feed even part of their populations while in the western world, problems result from producing too much food, including foods which need to be doctored with chemicals to make them acceptable to a public spoilt by choice.

We eat around 1.4 kilograms of artificial additives in our food every year. These include preservatives, anti-oxidants, stabilizers, emulsifiers, sweeteners, flavourings, bleaches, colours and water-retainers.

Preservatives keep foods bacteriologically safe and give them a longer shelf life. Some of the commonest preservatives used in meats are the nitrates and nitrites of sodium and potassium. These are effective against dangerous micro-organisms such as *Clostridium botulinum*, which causes botulism. These preservatives are also used to cure meats, such as bacon, and to give meat an attractive colour.

● A chemical diet

Scientists are researching the possibility that nitrates can be converted into nitrites in the stomach. Nitrites can combine with amines to form nitrosamines, which have proved in

Liposuction is a form of cosmetic surgery which involves liquifying excess fat, often around the thighs, then draining it off through vacuum tubes.

HORROR BURGER

The burger bun is now most often made with unbleached flour, but contains invert sugar, dextrose and emulsifiers, which are made from glycerin, fatty acids and tartaric acid. It also has flour improvers that contain ascorbic acid, which occurs naturally in many fresh fruits, and potassium bromate – a bleaching agent that destroys vitamin E and can cause nausea, vomiting and severe abdominal pains.

The burger should contain only pure ground beef and a flavour enhancer (monosodium glutamate) to make it taste more appealing. But some contain a preservative, sodium metabisulphite – this can cause gastric irritation and also reduces the food's vitamin B content. It can also be dangerous for asthmatics.

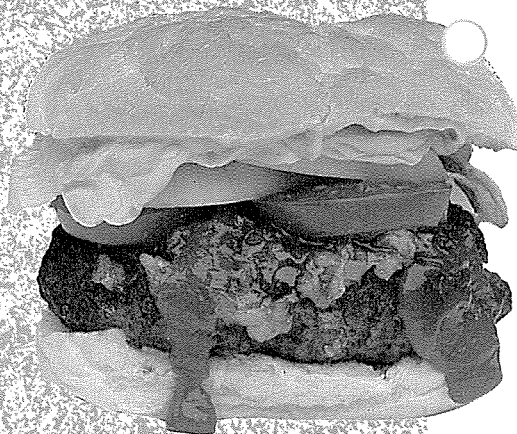
The extras – the processed cheese, salad, relishes and dressing also contain more than you may have imagined. The cheese contains emulsifying salts and potassium bromate. The salad

acid, a stabilizer to hold the bread mixture together, a dough conditioner such as azodicarbonamide to puff the bread up, and a bleach such as benzoyl peroxide. In addition bread may also contain residues of the pesticides, used to keep the grain unblemished.

● Synthetic colour

The food industry relies heavily on added food colourings to improve a food's appearance. Some, such as the yellow colouring 'tartrazine', are believed to affect some people with allergic conditions, resulting in asthmatic reactions, and are best avoided by asthmatics and hyperactive children. Tartrazine is one of the commonest of all food colours and is derived from coal tar. Other synthetic colourings are: Sunset Yellow, Cochineal Red A, and Chocolate Brown HT.

vegetables may contain traces of pesticides if they have not been washed properly. The ketchup and relishes contain preservatives and the mayonnaise contains edible gums, preservatives and a colouring agent. The chips that accompany your burger may well have been fried in animal fats.

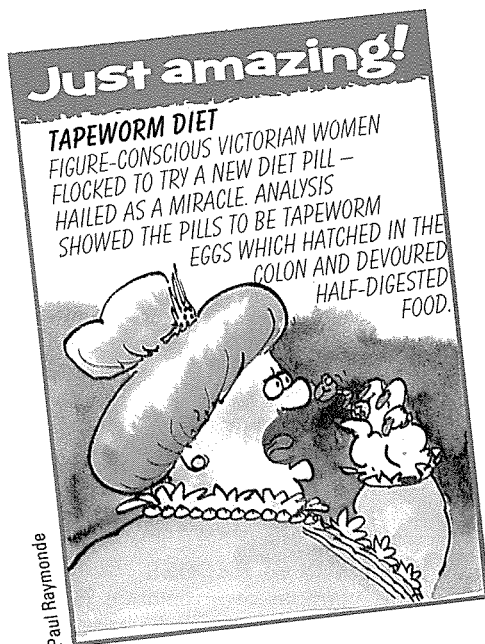


animal tests to be carcinogenic (cancer producing). We also take in nitrates from vegetables that have been grown with the aid of nitrate fertilizers (which also find their way into some water supplies). Nitrates and nitrites are banned in baby foods because nitrites de-oxygenate the blood. They have also been linked to asthmatic reactions in some people. Nitrates and nitrites are found in sausages, ham, tinned meats and some cheeses.

Some bread still contains one of the propionic acid preservatives, used specifically to kill off moulds. Many people believe it can cause skin diseases and migraine headaches. As well as propionic acid in one form or other, a white sliced loaf could well contain ascorbic

MEDICATED MEAT

Drugs administered to animals can remain in the meat after slaughter. The use of antibiotics as a cure-all in veterinary medicine has been responsible for causing allergic reactions in some people; furthermore, it could also lead to a resistant strain of bacteria. In the 1970s, doctors in Italy and Mexico noticed that small children were becoming sexually mature and that boys were developing breasts. In Italy this bizarre development was attributed to the growth-hormone diethylstilboestrol which had been injected into calves; in Mexico the cause was hormones fed to chickens. Hormone-fed meat is now illegal in EEC countries but is still sold in the USA.



TRAINED BODY

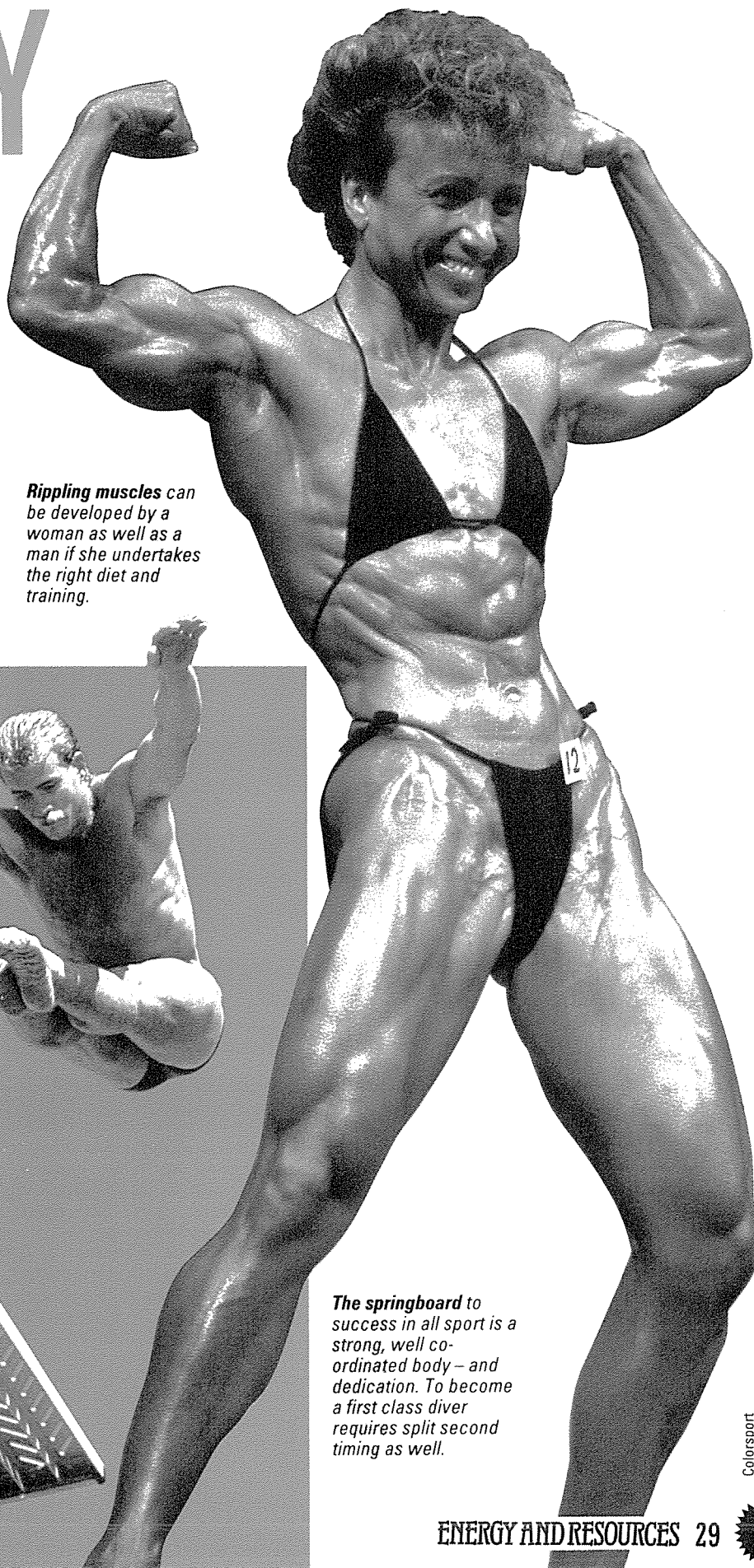
MUSCLE POWER
HEART POWER
BRAIN POWER

HIGHER LEAPS, LONGER jumps, perfect 'ten' scores in gymnastics and less and less time taken to cover distances – these are all proof that the human body, when trained well enough, can stretch itself to ever newer limits.

It has been calculated that if all the muscles in the human body were laid together so that they all pulled in the same direction, enough force could be developed to lift a double-decker bus.

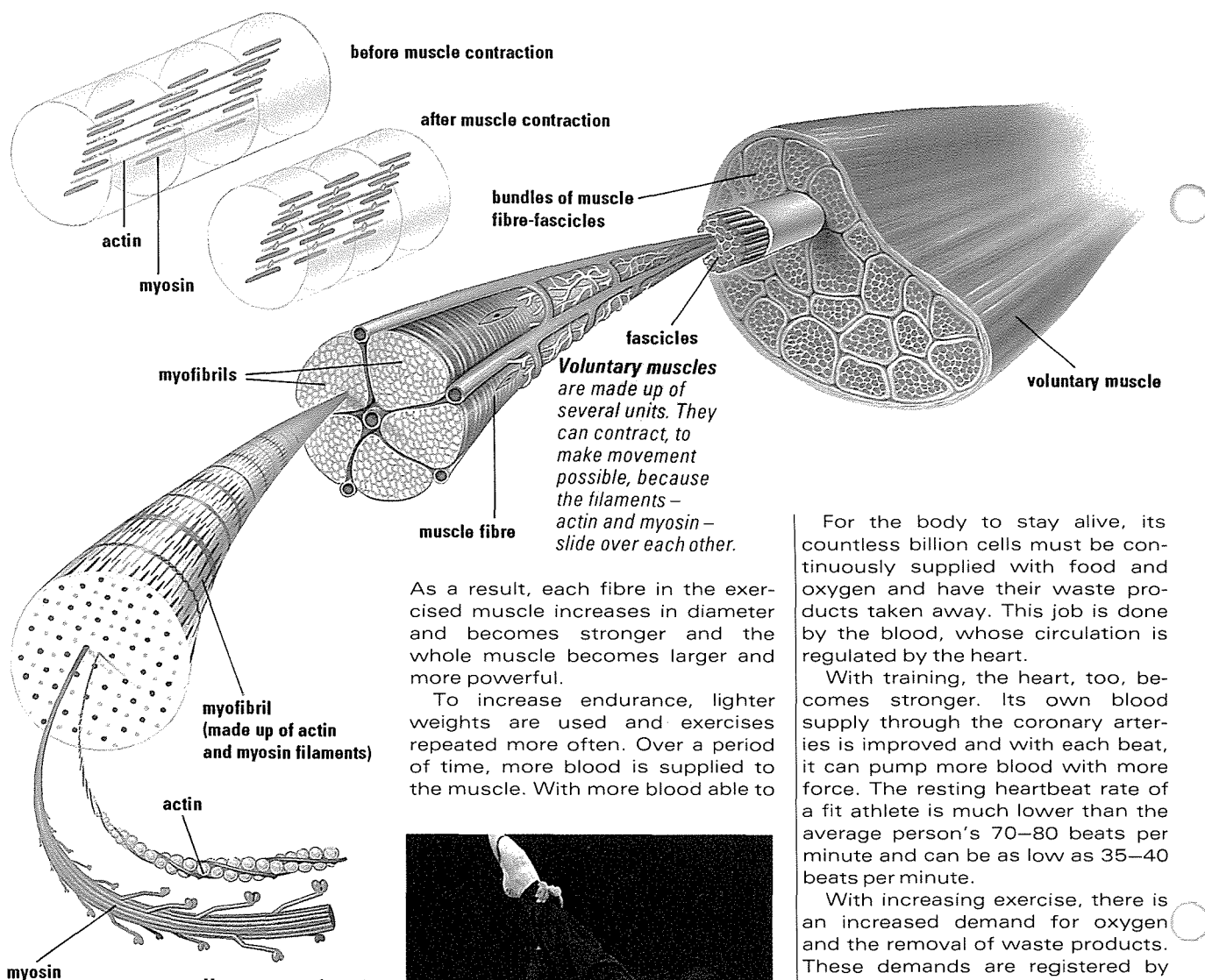
A special property of muscle lies in its ability to contract and produce force. A particular type of muscle transfers this force to bones where it is converted to movement by the many joints of the body. Joints must be tough enough to stop bones from coming apart under all

Rippling muscles can be developed by a woman as well as a man if she undertakes the right diet and training.



The springboard to success in all sport is a strong, well co-ordinated body – and dedication. To become a first class diver requires split second timing as well.





Voluntary muscles are made up of several units. They can contract, to make movement possible, because the filaments – actin and myosin – slide over each other.

As a result, each fibre in the exercised muscle increases in diameter and becomes stronger and the whole muscle becomes larger and more powerful.

To increase endurance, lighter weights are used and exercises repeated more often. Over a period of time, more blood is supplied to the muscle. With more blood able to

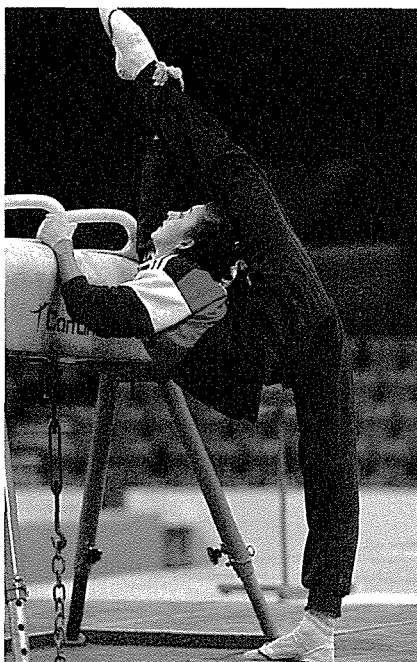
For the body to stay alive, its countless billion cells must be continuously supplied with food and oxygen and have their waste products taken away. This job is done by the blood, whose circulation is regulated by the heart.

With training, the heart, too, becomes stronger. Its own blood supply through the coronary arteries is improved and with each beat, it can pump more blood with more force. The resting heartbeat rate of a fit athlete is much lower than the average person's 70–80 beats per minute and can be as low as 35–40 beats per minute.

With increasing exercise, there is an increased demand for oxygen and the removal of waste products. These demands are registered by the nervous system which stimulates changes within the heart and blood vessels. The increased heart rate and blood flow remove the waste more quickly and supply more oxygen and glucose to the muscles at the same time.

Co-ordination

Powerful muscles and a good circulation are necessities for successful athletes. But no matter how



Supersport Photographs/Eileen Langsley

Hyper-extension: the gymnast can stretch her body into unusual positions thanks to the strength and suppleness of her well-trained muscles.

the stresses that the muscles put on them and flexible enough to allow smooth action.

Because these muscles are connected to the skeleton they are sometimes known as skeletal muscles. They are under the command of that part of the brain that we can control by our thoughts and are, therefore, called voluntary muscles. They are capable of fast, almost explosive, contraction. The forces that muscles can put on bones can sometimes be so great that they actually create stress fractures.

Pumping iron

To prepare the body for sport, it must be made used to new demands: more strength, more endurance, greater suppleness and better co-ordination.

Weight training and multi-gyms are used by many athletes to improve their muscular performance. Heavy weights are used to develop strength and exercises are repeated just a few times at each session.

flow through the muscle, more food can be supplied to it to keep it working and, just as important, the waste products can be more efficiently removed from it.

In both sorts of training, it is thought that the sub-cellular powerhouses of the muscle cells – cigar-shaped bodies about $\frac{1}{300}$ mm long, called mitochondria – increase in number. As a result, they can convert more glucose into ATP (adenosine triphosphate) which actually gives the cell the energy to contract. This process is called cellular 'respiration'.



Paul Raymond



EATING TO WIN – MAXIMIZING ENERGY SUPPLIES

An important source of energy for the body is glycogen – the form in which carbohydrate is stored in the body. Scientists have found that if the body's level of glycogen is first completely run down, it can then be 'superloaded' to more than two or three times its original level.

Athletes who take part in endurance sports, such as running, cycling, swimming or hockey, need to build up a maximum reserve of energy for the competition. They do this by following a regime called glycogen supercompensation, or carbohydrate loading, for six days beforehand. Typically this consists of:

• The depletion phase

DAY ONE:

Training: to exhaustion to deplete glycogen in muscles

Diet: normal

DAYS TWO AND THREE:

Training: light, to continue depletion of glycogen

Diet: high in fat and protein, very low in starchy carbohydrate

• The loading phase

DAYS FOUR, FIVE AND SIX:

Training: very little or none

Diet: build up carbohydrate intake.

At least 70 per cent of total calories consumed must be from starchy carbohydrate: plenty of bread, pasta, cereals and potatoes.

• The pre-competition meal

Easy to digest, high in carbohydrate, low in fat and protein (eg baked potato and cottage cheese; large green salad). Three glasses of liquid.

A modified version, without the high fat and protein diet of days two and three, recommends:

• For three days before competition:

Training: reduced markedly.

Diet: high in starchy carbohydrate.



Mark Shearman

fit the body is, if its various parts cannot act together at the athlete's will, very little activity, let alone sport, can be undertaken. The organ that co-ordinates the various parts of the body is the brain. This is where all decisions are taken.

As the tennis ball flies towards the player, the eyes note its swift passage and send messages via the sensory nerves to the brain. Here, the message is decoded and interpreted as sight. Most of the delay in response, what we call reaction time, is really the brain deciding what to do. All options must be calculated with speed and accuracy if the ball is to be returned.

• Perfect response

The body's response is a whole-body response. It is not just the racket arm that must be swung to meet the ball hurtling towards it. The feet must be in the right place, the balance must be right and already the brain must be calculating where next to move if the ball comes back again from the server.

The part of the brain that does the co-ordinating of this whole-body effort is the cerebellum, a branching, tree-like part of the brain situated near where the spinal cord swells out to form the brain itself.

It is normally regarded as a 'lower' part of the brain because it is not directly under the control of conscious 'will'. However, without it, even relatively simple actions, such as lifting a cup to the mouth and drinking from it, would be virtually impossible. It is the cerebellum that takes in all the little bits of information about what is a successful movement and what is not and puts

it all together for us as a 'package' of movement instructions. Practice and training educate the cerebellum.

• Balancing act

Shut your eyes. Think about your body. Where are your feet? Your arms and hands?

All the body's skeletal muscles have sensory nerve endings in them called stretch receptors. These stretch receptors detect continuously how extended or contracted each muscle is. From all this information that it receives, the brain works out the configuration of the body at each movement.

When the information from these

sensors is interrupted (as happens when a pain-killing injection is given or when the blood supply is restricted, giving the sensation of 'pins and needles') the brain cannot sense the affected parts.

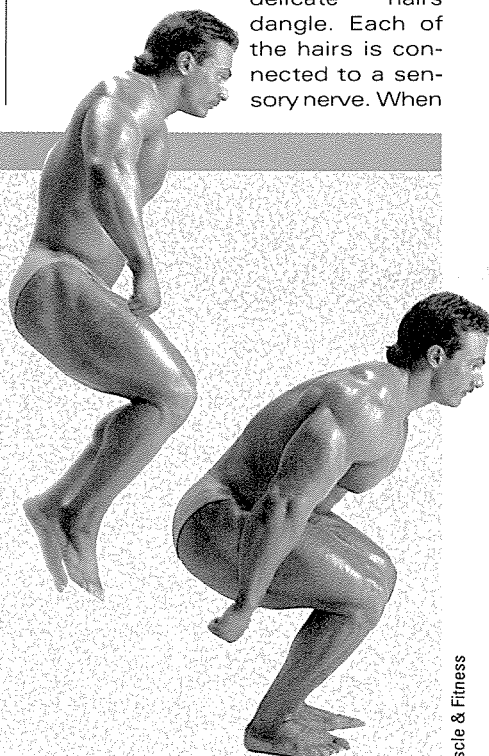
In addition to this body-shape information, the brain also works out which way up the body is and if it is tilting or not by using two sets of balance organs which are situated on the sides of the head, one behind each ear. Each consists of three fluid-filled canals, into which delicate hairs dangle. Each of the hairs is connected to a sensory nerve. When

THE HIT METHOD

This technique is designed to develop explosive strength and speed – it is mainly used by sprinters and jumpers. The idea is to hit a fixed, resilient surface with the feet and bounce off it. The athlete stands on a raised platform; steps off, lands on both feet, then leaps as high as 75–100 cm into the air. A leap to 75 cm builds up speed; to 100 cm, strength.

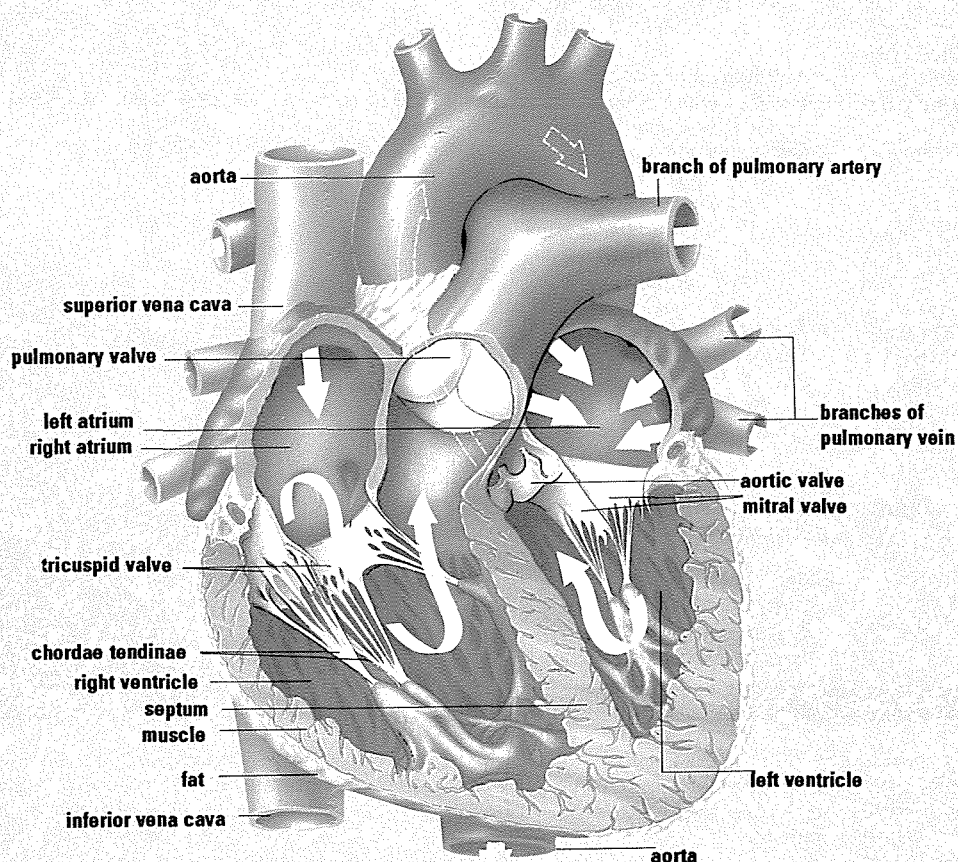
In the USSR, swings and sledges are also used. As the seated athlete comes forward on the downward swing, he pushes off against a platform with maximum force and swings back. In the sled, he slides down an incline, meets a wall with his feet and pushes off it back up the incline.

The hit method is *only* suitable for trained athletes who are already very fit and strong and must only be carried out under careful supervision as it is a potentially highly dangerous technique.



Muscle & Fitness

THE ATHLETE'S HEART: AN EFFICIENT PUMPING MUSCLE



arrows show blood flow through the heart

Just like any other muscle, the heart will respond to a specific training programme. Unlike skeletal muscles, the heart is an involuntary muscle, pumping blood and keeping it flowing throughout the body. The adult human body contains 5 litres of blood.

- the amount of blood pumped by the heart of an average person is 5–6 litres per minute
- in highly trained endurance athletes, it can be 40 litres per minute
- the number of times the heart beats – the pulse – in an average person is 70–80 per minute
- the athlete's pulse can be as low as 35 per minute

Aerobic training, such as running or swimming, has several beneficial effects on the heart.

- it can make the heart more efficient: more blood is pumped per beat
- during exercise, more blood goes to the exercising muscles and less to the non-essential areas
- the size of the heart may increase

flexibility and balanced co-ordination than gymnastics: the brain has to work like a turbo-charged computer to take in all the information from stretch receptors and balance organs so that the gymnast lands on his or her feet, and does not fall off the narrow beam, bars or 'horse'.

Maximizing momentum

Karate is probably one of the best-known martial arts. The force of the karate blow depends mainly on two things: the speed of the part of the body being used just before impact (velocity) and its weight (mass). By multiplying velocity by mass a measure called momentum is obtained. The higher the momentum of a body, the more force it is able to exert. So a light-weight travelling fast can deliver the same amount of force as a heavy-weight travelling more slowly.

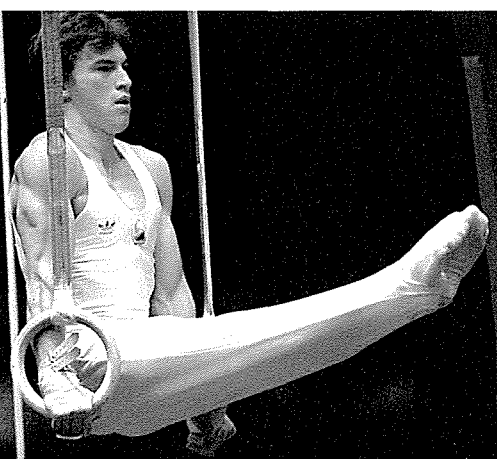
The skill of karate lies in making the punch as fast as possible and in making the effective weight as great as possible.

The same principles are at work in boxing, but the range of blows that are allowed is less. The classic position is sideways, with the trailing leg ready to brace the body forward so that the whole weight of the body can go into the punch.

Another important difference be-

tween karate and boxing is, of course, that boxers wear gloves which are packed with stuffing.

A very important aspect of the destructive power of a punch is the time it takes to transfer its momentum to the opponent. The quicker the change of momentum, the greater the force. A punch that delivers its momentum in one-tenth of a second would have twice the force if it did the same in half the time.



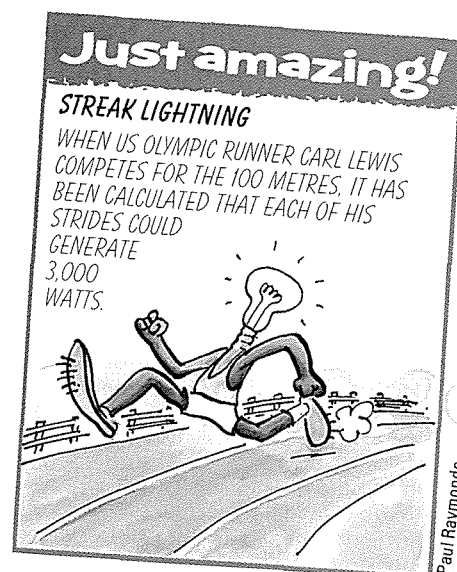
Allsport/Bob Martin

Jack-knifed in mid-air – the gymnast requires incredibly strong abdominal muscles to maintain this position for the required two seconds.

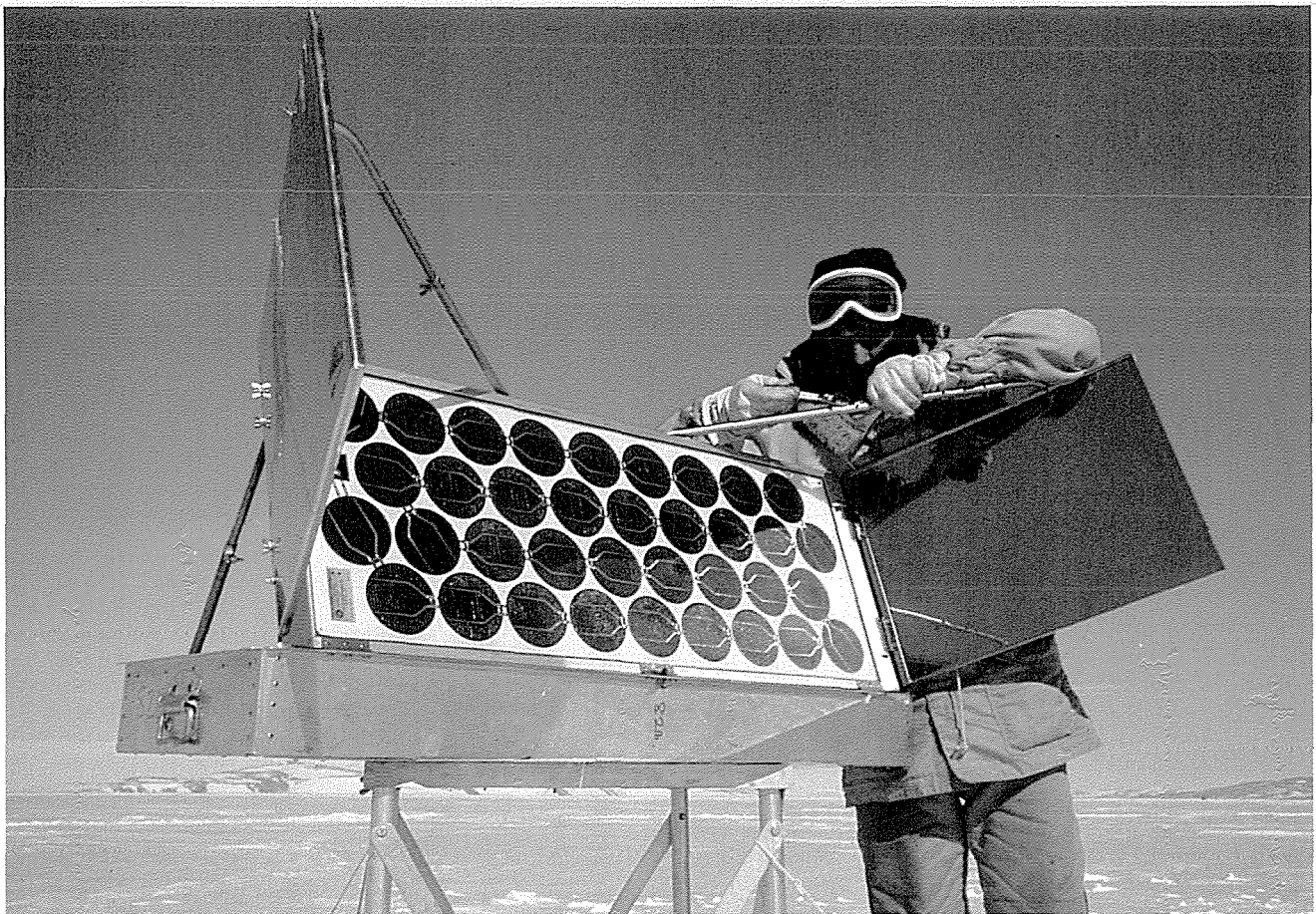
ever the fluid is set moving in relation to the hair, the hair bends and a message is sent to the brain.

The three canals are all connected to a sac-like structure – the sacculus – that tells the brain which direction is down. It is when this part of the balance organ gets confused that we get that funny feeling in the stomach, as when a lift suddenly starts to descend.

No sport better combines muscle



Paul Raymond

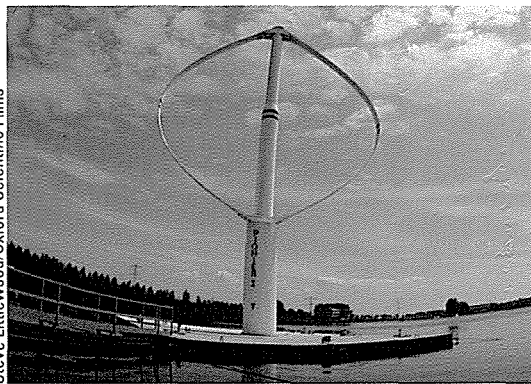


Kim Westerskov/Oxford Scientific Films

- ☒ WIND TURBINES
- ☒ WING SAILS
- ☐ PHOTOVOLTAICS

DURING THE 1970s, THE PRICE of oil shot up on two occasions. This generated a lot of interest in renewable forms of energy not involving expensive fossil fuels, such as coal and oil.

Steve Littlewood/Oxford Scientific Films



Photovoltaic cells convert light into electricity; this means they can be used in very cold climates – even in the Antarctic. The electricity produced is stored in batteries.

Vertical wind turbines are still experimental. Unlike horizontal wind turbines, they do not have to be turned into the wind in order to operate at maximum efficiency. This makes the construction of vertical turbines much simpler.

NATURAL POWER

All these energy sources – wind, sunshine, waves, bio-energy – are ways of capturing the enormous amount of energy poured on to the Earth's surface by the Sun. The most direct way of doing this is to harness the wind. Highly efficient modern windmills are already being used for generating electricity on the Orkney Islands and in other small communities too remote to receive normal electricity supplies. In this type of situation, the high cost of building the windmill is balanced by the convenience of electrical power.

The biggest windmills look like giant aircraft propeller blades and are known as horizontal wind turbines. When the wind hits the blades, they revolve and drive an

Wind farms consist of hundreds of small wind turbines. Together the machines generate enough electricity to be economic, but because so many are needed, the farms can only be built in places with land to spare.

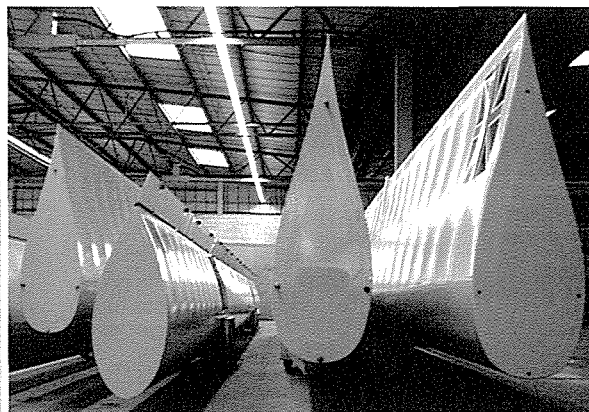
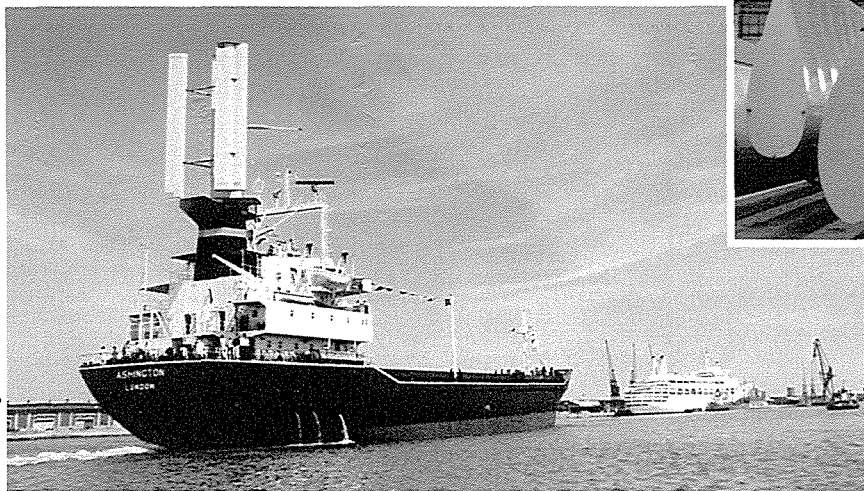


Tim Davis/SPL

Wing sails are computer-controlled to make the most of the wind. But ships are still fitted with engines so their speed can be maintained when there is no wind.

Walker wing sails have a tear-drop cross section to maximize power and minimize drag. Sails and computer software are tailored to each ship for maximum efficiency.

Walker Wingsail Systems



are harnessed by pilots making flights from west to east. By careful planning, they can make faster crossings and use less fuel simply by cruising at the jet stream altitude.

The heat of the Sun can be used directly by designing buildings with plenty of insulation and large windows on the side that faces the

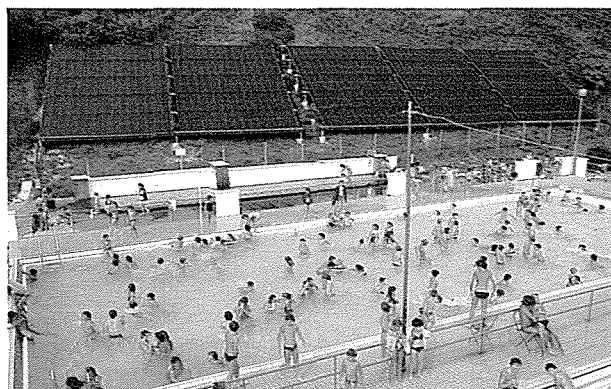
electric generator, which is usually connected straight on to the main propeller shaft.

By the 1990s the total amount of electrical power generated worldwide by wind was about 1,500 megawatts — almost all of it in California, in the USA, where the tax system encourages this form of generation. This is about one and a half times the output of a single, large, coal-powered, electricity generating station. About ten per cent of world electricity output could be generated using wind power but, so far, the cost is too high to make it worthwhile.

Wind farms

Wind power is very attractive because it is one of the very few energy sources that is genuinely pollution-free. On the other hand, large wind farms sited on the coast would ruin the scenery and fill the

Solar panels, such as these, consist of aluminium slats that absorb the heat of the Sun, and small bore pipes through which water circulates. Small panels are sometimes used to heat water for the home, but large installations are more successful. These are generally used for heating buildings and swimming pools.



Sebart/Can

countryside with a loud swooshing sound.

Far out to sea, the wind blows strongly almost every day, so the supply of wind power should be quite reliable. To take advantage of this, there are proposals to build floating platforms carrying several large wind turbines driving electrical generators. However, transmitting the power back to the land is a major problem at present.

High altitude winds or jet streams

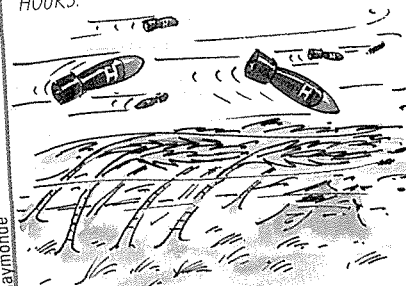
Sun. The windows are glazed with 'low emissivity glass' that lets the Sun's rays into the building but prevents heat escaping. This is the same principle as the greenhouse, which has been a way of exploiting the Sun's heat for centuries.

The Sun can also be used to heat water using solar panels. These are elaborate heat-exchangers, often fitted on roofs as part of the domestic hot water system, to substitute an ordinary boiler.

Just amazing!

NATURE'S H-BOMB

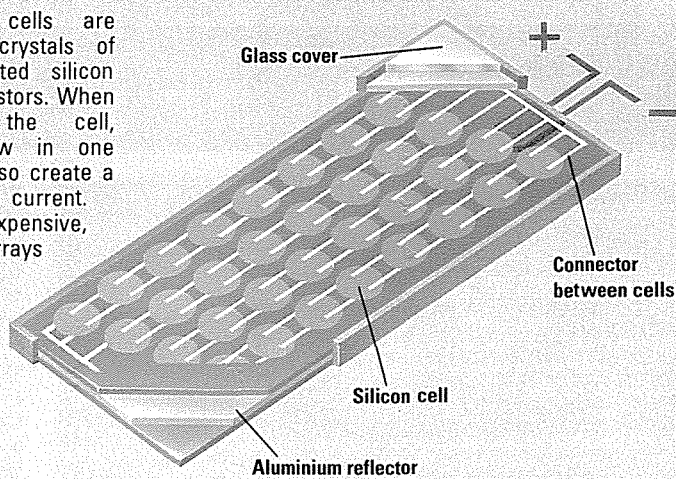
A FULLY-DEVELOPED HURRICANE PUMPS 2 MILLION TONS OF AIR PER SECOND UP INTO THE EYE OF THE STORM AND OUT AGAIN, RELEASING ENERGY EQUAL TO 400 HYDROGEN BOMBS EVERY 24 HOURS.



Paul Raymond

ELECTRICITY FROM SUNLIGHT

Photovoltaic cells are made from crystals of specially treated silicon just like transistors. When light hits the cell, electrons flow in one direction and so create a small electric current. Although expensive, photovoltaic arrays last for up to 20 years without any need for maintenance.



FUELS OF THE FUTURE

-  OIL FUEL PRODUCTS
-  PETROL POLLUTION
-  CLEANER FUELS

WASTE FROM CHICKENS and other animals may provide the fuel of the future. Bacteria can change these wastes into a gas mixture rich in methane, which can be used instead of petrol. The use of methane would avoid a fuel crisis when oil supplies dwindle and would cause much less pollution than petrol.

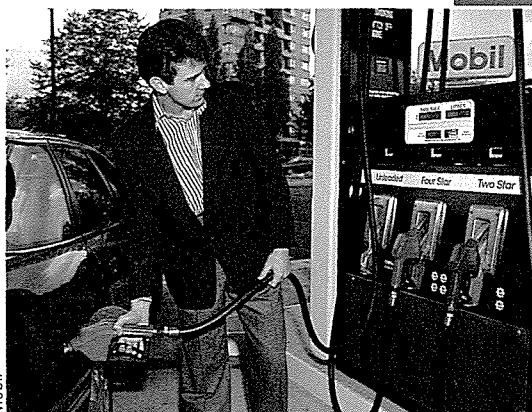
Oil refineries produce a large range of chemicals, including many fuels. These include fuel oil, diesel oil, kerosene, petrol and petroleum gases. Diesel fuel is becoming increasingly popular for road vehicles because it is cheaper to produce than petrol. Also, it has the great advantage that it does not have lead added to it – lead causes pollution.

Lead compounds are added to ordinary petrol to improve its octane rating – a measure of how smoothly it burns. This helps to avoid violent explosions (called knocking) in the engine. Lead also helps to lubricate the engine pistons. New laws say that, to reduce lead pollution, unleaded petrol must be generally available in Europe from October 1989, so alternative anti-knock additives will probably be needed.

Fighting pollution

Petrol engines produce several kinds of pollution when the petrol-air mixture ignites. The lead-containing compounds produced can build up in human nervous tissues and in the brain, and may affect intelligence – especially in the unborn and in growing children.

Sunlight acts on the oxides of nitrogen formed to produce smog.



Mobil

Unleaded petrol for greatly reduced pollution is dispensed through a nozzle that is colour-coded green.

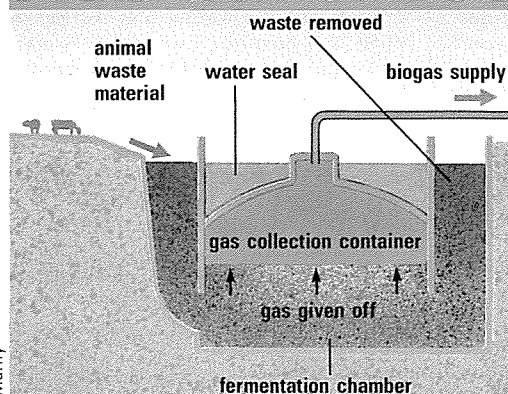
Waste gas is burnt off at an oil refinery, where fuels and other petroleum products are obtained from crude oil.

This consists of compounds that irritate the nose and throat and can sometimes kill. Carbon monoxide is much more dangerous. Even a small amount leaking from a defective exhaust system into a car can cause illness or death.

Ozone is another harmful gas produced by petrol engines. High in the atmosphere, ozone screens out harmful ultraviolet radiation in sunlight. But it is no good to us at ground level. It is poisonous and may also help to cause harmful acid rain.

One way of tackling lead pollution

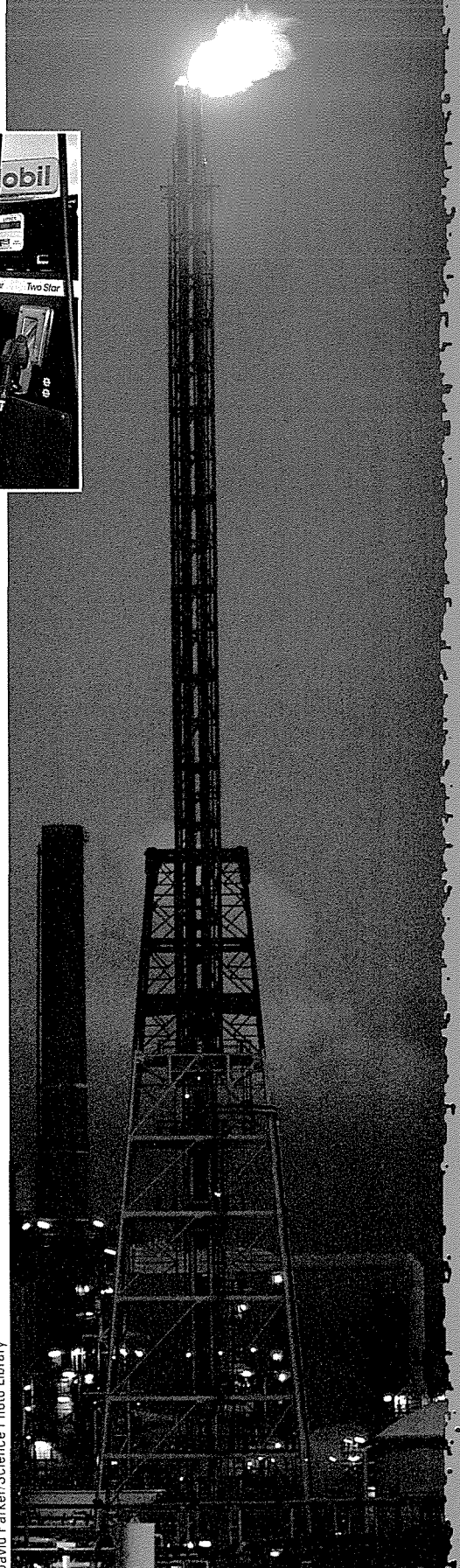
BIOGAS – FUEL FROM WASTE

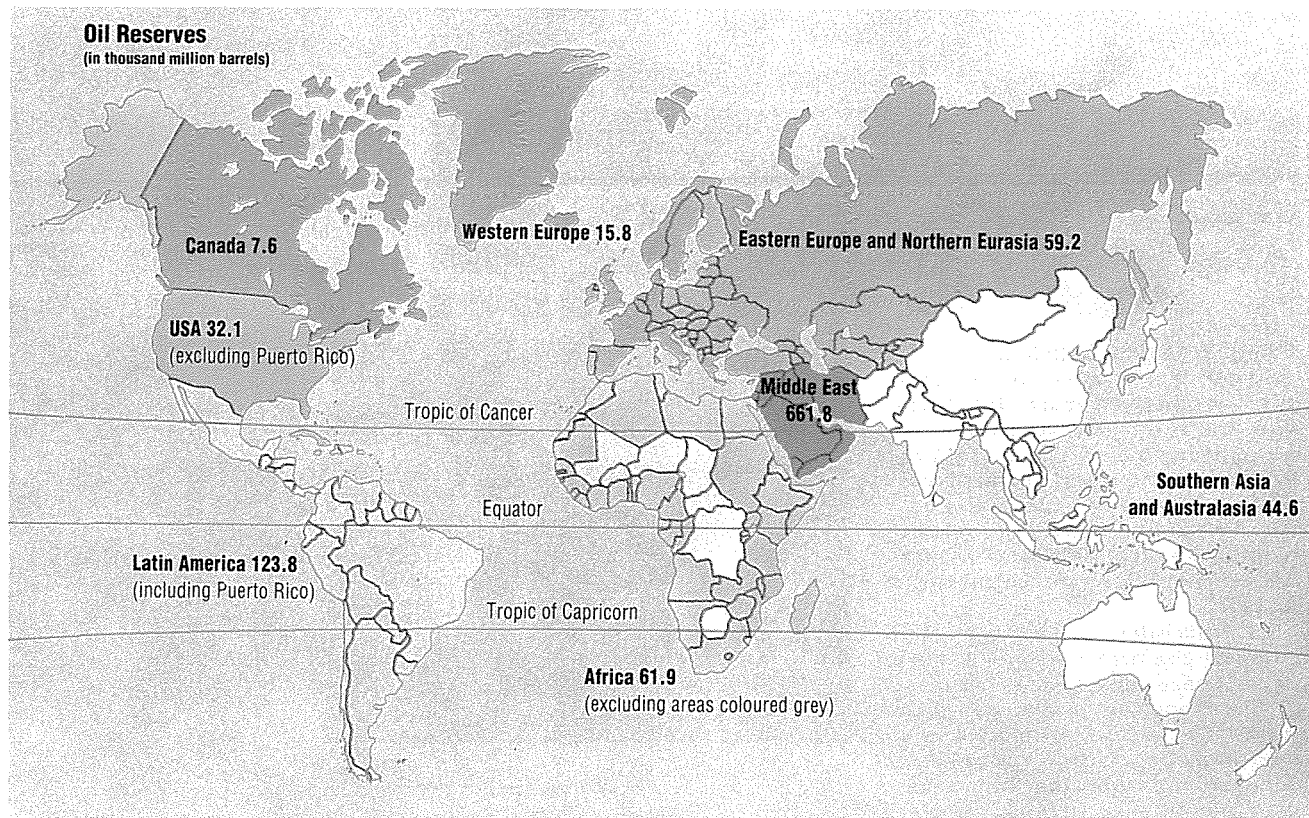


A digester unit can convert animal waste material into a methane-rich gas mixture that can be used as fuel. The waste flows down into a fermentation chamber, where it undergoes chemical changes. During this process, it gives off gas, which is trapped in a storage tank above. About 70 per cent of this biogas is methane, which can be used as fuel in engines. When no more gas is given off, the waste material can be used as fertilizer.

Janos Marffy

David Parker/Science Photo Library





is to develop lean-burn engines, in which less fuel is mixed with a given quantity of air. The fuel is burnt more efficiently and at a lower temperature. This reduces fuel consumption, and the exhaust contains far less lead and other polluting materials.

The European Community, following the United States' lead, requires all new vehicle engines to become cleaner during the 1990s. In the near future, expensive devices called catalytic converters will be needed to remove harmful substances from exhaust fumes in order to comply with the new laws. The authorities are also insisting that lead-free petrol be put on sale in all its member countries.

In 1973 oil prices soared. Poor countries were especially hard hit. One of them, Brazil, reacted by promoting a new fuel for its cars — alcohol made from sugar-cane juice. The alcohol was ethanol, or ethyl

Brazil's sugar cane crop is now providing some fuel for cars. Yeast converts the sugary juice from the cane into ethyl alcohol, which can be used in engines as a substitute for petrol.



Hutchinson Library

The Middle East, although a relatively small area, is a major oil producing region possessing over 60 per cent of the world's oil reserves.

Just amazing!

SLICK FUEL

ONE AMERICAN UNIVERSITY RUNS ITS BUSES ON USED COOKING OIL, SUITABLY FILTERED BEFOREHAND TO REMOVE BITS OF FOOD.



Paul Raymond

alcohol, produced by the fermentation of cane sugar. It was either blended with petrol or used 'neat'. Two million cars have been converted to run on pure ethanol.

Other vegetable crops have been used as motor fuels before. Vegetable oils were used in the first diesel engines. Now they're being experimented with again as a possible source of cheap fuels in the Third World.

Running on gas

Engines can be run on methane gas. One source of this is waste from chickens and other animals. The wastes are broken down by bacteria in airtight containers to form a 'biogas' that is typically 70

per cent methane and 30 per cent carbon dioxide.

Even more appealing is the possibility of getting fuel from water. When an electric current is passed through it, water splits up into hydrogen and oxygen gases. The hydrogen could be used to fuel vehicles, and the only waste product would be water vapour.

Another alternative to oil is synthetic liquid fuel, which is generally known as synfuel. Coal can be liquefied by adding hydrogen gas to it at a high temperature and pressure. Tar sands and oil shales can also be processed to produce synfuels. All these sources of fuels may provide some insurance when oil becomes too expensive.

PEDAL POWER

- ALUMINIUM FRAMES
- SOLID WHEELS
- COGGED BELTS



Tony Stone Photo Library, London

BICYCLES ARE ONE OF THE cheapest forms of mechanical transport. The traditional 'sit up and beg' machine gives freedom from footslogging to European schoolboys, African peasants and millions of other people around the world.

The average adult cyclist produces about one eighth of a horsepower, which can easily propel a cyclist at 15 km/h. Most people are comfortable turning the pedals at about 60 or 70 revolutions per minute. For maximum efficiency and speeds above 15 km/h, bikes need gearing systems that allow the rider to keep pedalling at this number of revolutions, whether he or she is going slowly up hill or speeding on a level road.

Steel is the traditional material for



Photosport International

BMX bikes have small wheels and straight forks for fast steering responses. Saddles are low and set right over the back wheel for good balance. Road racers (inset left) sit further forward and with the head down for lower wind resistance. The small front wheel, dropped handle-bars and solid wheels also help the aerodynamics.

bike frames and components because it is strong and fairly cheap. Steel tubes are assembled into bike frames using steel joining pieces known as lugs. Molten brass is used to fix the tubes in the lugs and when the tubes are assembled into the traditional double-diamond shape, bike frames are surprisingly

light and rigid. The process of joining the tubes with molten brass is known as brazing.

Stronger alloy steels are constantly being developed, which allows bike manufacturers to use thinner and therefore lighter tubing. Unfortunately, this puts up the cost and multiplies production problems because the alloy content of the steel can easily be destroyed if the steel is overheated during the brazing process.

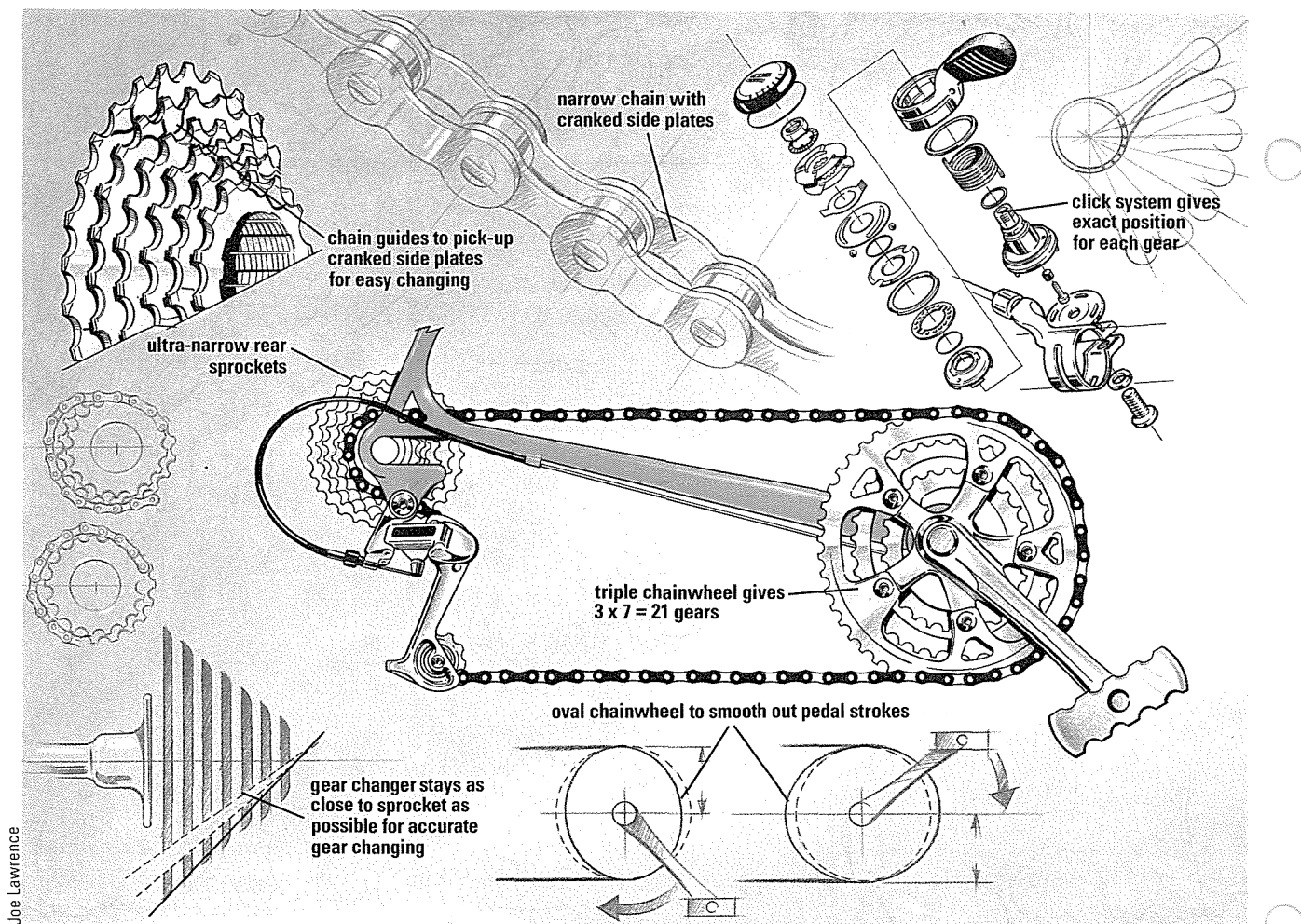
To get round this problem and to make bikes lighter and more aerodynamic, an ever-expanding range of materials is now being used. These materials include:

- light aluminium alloys for frames
- titanium to replace steel for components like brakes, gears and pedals
- composite plastics for frames and wheels
- moulded plastics for saddles, wheels and fairings
- carbon fibre for wheel rims.

In China, bikes are a cheap and popular form of transport. Cyclists are separated from the rest of the traffic to ensure that buses and official cars can get through. Enormous cycle parks are dotted throughout Chinese towns.



Tony Stone Photo Library, London



Joe Lawrence

Nevertheless, for the moment, most sports and racing bikes are still made from steel, though the best ones now have aerodynamic tear-drop shaped tubes. These absorb less energy as they move

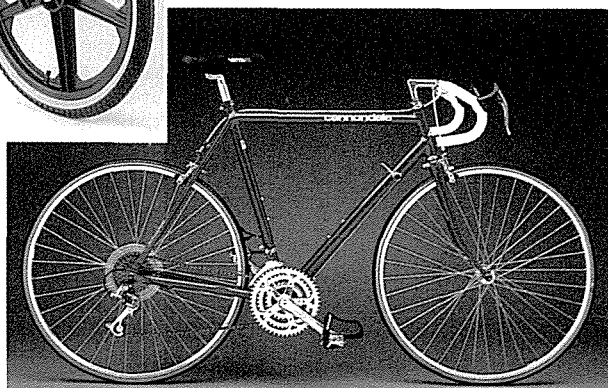
through the air but are difficult to manufacture. There are also more aluminium frames being built as manufacturers find better ways to join the tubes together into frames.

When aluminium was first used for bike frames, engineering adhesives and metal pegs were used to fasten the tubes together; but now that low-temperature aluminium welding has been developed, the joints can be welded. However, all welding and brazing processes tend to weaken the metal, while adhesives are difficult to use for mass production. To get round this, aluminium frames are now in large scale production using separate lugs to join the tubes in the same way as traditional steel frames. During assembly, the frame tubes are forced on to the lugs using

Derailleur gears for Mountain bikes have up to 21 gears to cope with the hills. Each of the three chainwheels can be used with each of the seven sprockets on the back wheel, making 21 gears in total. In the heat of the action, gear changes must be smooth and accurate, so the chain links and the sprockets are specially shaped to work together.



Moulded plastic wheels are fitted to some BMXs to save spoke breakages on touchdown. Sports bikes (right) with frames made from aerodynamic aluminium tubes keep the traditional shape.



Cannondale Corporation

Just amazing!

SHAKE IT ALL OVER

THE FRONT FORK IS THE MOST HIGHLY STRESSED COMPONENT OF A BICYCLE FRAME. IN TESTS IT MUST BE CAPABLE OF WITHSTANDING EIGHT MILLION OSCILLATIONS, EACH DEFLECTING THE ENDS OF THE FORK BLADES BY 15 MM.



Paul Raymond

PEDAL POWER

Cannondale Corporation



Aluminium frames have large radius welds, so the stresses on the joints are spread over a large area of the tubes. Weldless aluminium frames (left) have joints called lugs – the tubes are a tight fit on the lugs so they never come apart.

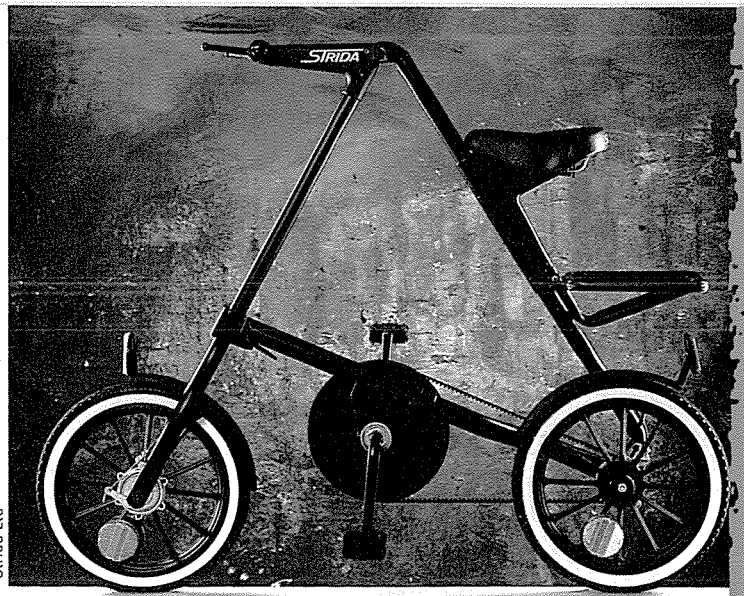
Cycles Peugeot

hydraulic pressure only, applied by specially designed machines.

Composite materials and light-weight titanium metal were first used by cycle designers when building racing bikes to break the Hour Record – the number of kilometres that can be packed into an hour's continuous riding. These Hour Record bikes were far too uncomfortable for normal purposes,

Folding bikes are fitted with small wheels to make them easier to handle and store. Small wheels do not smooth out bumps in the road, so thick, wide tyres are fitted to improve the ride. Unfortunately this increases 'rolling resistance' – a force caused by wheel distortion and opposing forward motion.

Strida Ltd



but they did free designers from their fixed ideas about the shape of bicycles.

Many of these new shape frames and solid wheels can only be made using resin composites reinforced by high-strength fibres such as Kevlar and carbon fibre. These materials allow stiff and strong bike frames to be made in a much wider variety of designs. They are also resilient and springy, which makes them ideal for Mountain bikes and BMXs.

Town bikes

During the late 1980s, the Mountain bike with 18-speed or 21-speed gearing became very popular. But the main design feature is that the rider sits bolt upright, so aerodynamic efficiency is inevitably very poor. Nevertheless Mountain bikes are popular in town as well as country, especially among bike

messengers, because they can be ridden up and down kerbs and are very comfortable for short journeys.

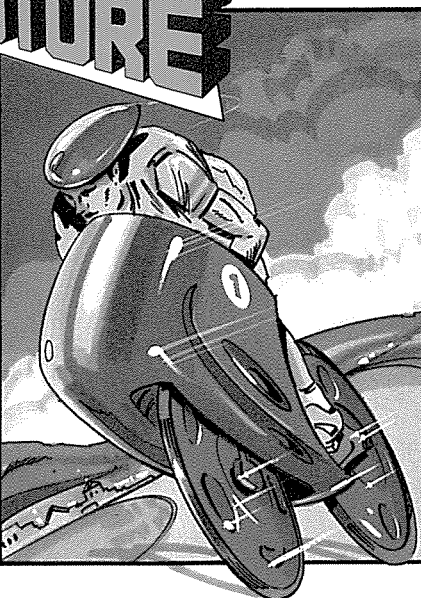
The latest folding bikes have a frame made of aluminium, which gives a comfortable ride because it does not transmit shock in the way that steel does.

The biggest step forward so far as most people are concerned is that the messy chain has been replaced with a maintenance-free cogged rubber belt. Work is going on to develop a hub gearing system for use with a belt drive.

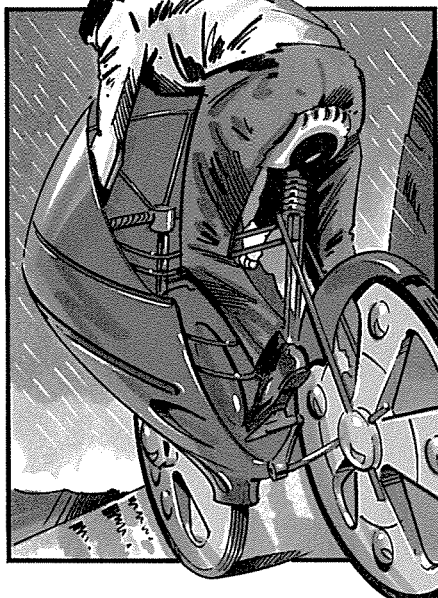
Bicycles are such an efficient user of energy that in some towns of East Asia, basic passenger transport depends on cycle rickshaws, or tri-shaws. Two passengers sit over the twin front wheels of the tri-shaw and the whole thing is propelled by the one eighth of a horse-power produced by the tri-shaw operator.

INTO THE FUTURE

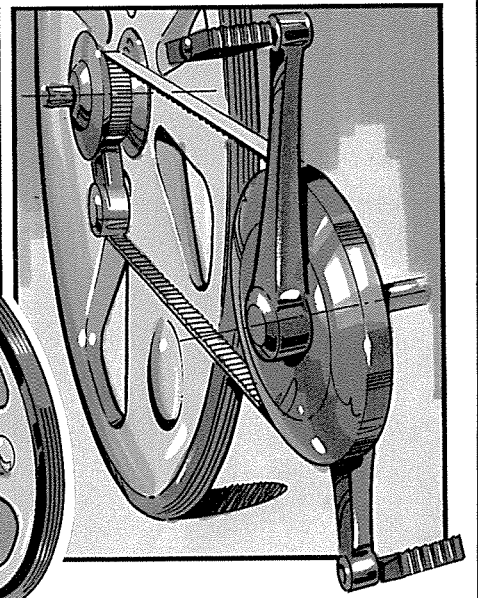
Joe Lawrence



▲ Streamlined bicycles will raise the average rider's speed from 24 km/h to 40 km/h, while racing cyclists will average 64 km/h for up to seven hours.



▲ The fairing and wheels will be supported by a network of narrow tubes. Behind the fairing, the rider stays warm and dry whatever the weather.



▲ Power will be transmitted by a maintenance-free rubber belt. The gearing system will be stepless, using expanding pulleys and hydraulic control.

ROUGH TERRAIN VEHICLES

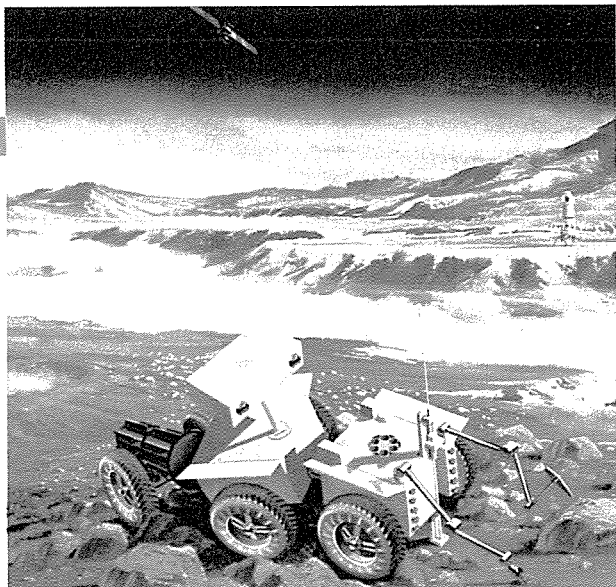


VIEW ROUGH TERRAIN VEHICLES

BHC/Westland Aerospace

Unmanned planetary exploration vehicles are built up from separate modules so they can travel over very rough surfaces and not be upset. They analyse samples and send the results back to Earth by radio.

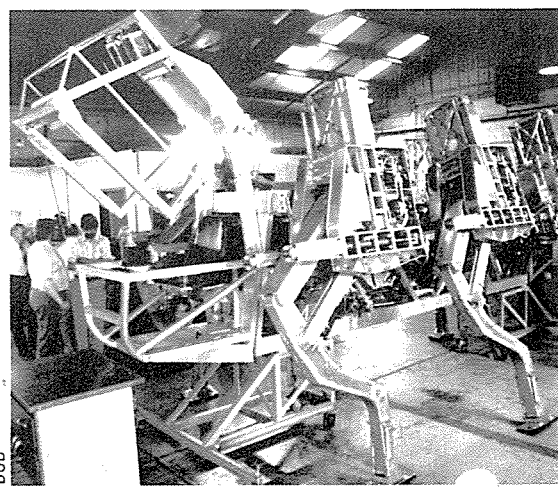
Ground effect machines, usually known as hovercraft, can cross almost any terrain because they are supported on a cushion of air. In this case it is retained by an inflatable rubber skirt right around the perimeter.



NASA

The American ASV (Adaptive suspension Vehicle) has a maximum speed of 5 km/h over rough ground.

Dune buggies are home-made leisure vehicles for use among the empty sand dunes of southern California. Big tyres and a powerful engine are essential.



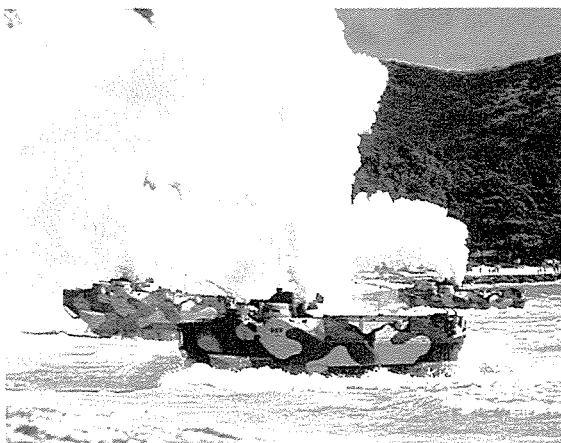
DOD



Mary Fisher/Colorific!

Mars Ball has a system of gas bags that inflate and deflate in sequence; this propels the vehicle slowly across the planet's surface.

Lori Stiles, University of Arizona



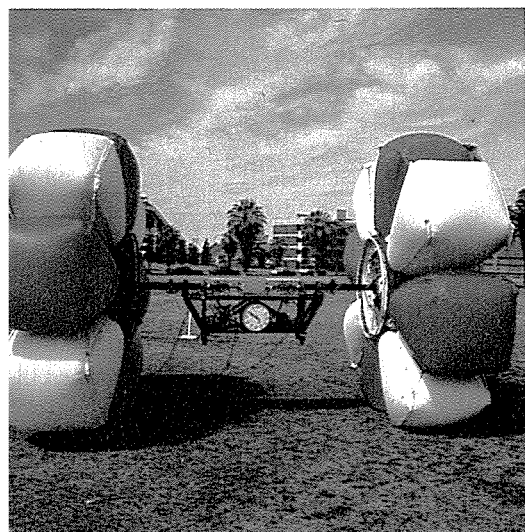
Snowmobiles fitted with skis and powered by a motorcycle engine can reach up to 50 km/h. Some versions are used for polar exploration.

Amphibious landing craft are now equipped with a small cannon to suppress defensive fire, and smoke generators to conceal movement up the beach.

DOD



Yamaha Motor Canada





-  UNIVERSAL BEAMS
-  STRESS GRADING
-  REFLECTIVE GLASS

TODAY'S MATERIALS

THE CORRECT CHOICE OF materials for each part of a structure is one of the most important jobs that architects and engineers do during the design phase of any project.

Cement is the universal building material because it can do many different jobs, depending on the way it is mixed. It can be used as

- a weak mixture of sand and cement for laying bricks and lightweight blocks
- a strong mixture of sand and cement with silicon additive for making a waterproof layer inside or outside buildings
- a mixture of sand, cement and gravel making a weak concrete suitable for floor slabs and foundations
- a mixture of sand, cement, stones and detergent for making full strength structural concrete.

Bricks are made from clay that is shaped in a mould, then fired in a kiln. Thousands of different types of brick are produced, mainly because the colour and quality of the clay used to make them varies according to the clay pit it is dug from.

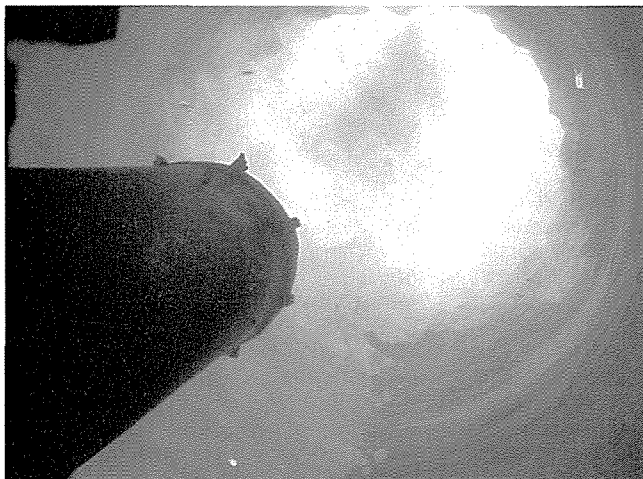
The cheapest bricks are known as Flettons and are normally made from Oxford clay. This type of clay contains a certain amount of carbon. The brick kiln is filled with newly-moulded bricks, then heated by gas. Half way through the process, a temperature is reached that starts the carbon in the clay itself burning. From then on, the gas to the kiln can be turned off and the carbon acts as the 'fuel' for the rest of the process. Unfortunately, flettons have an ugly, burnt look, so they are only used where they will not affect the final appearance of the building.

Mirrored glass is fitted to air conditioned buildings to keep the sun out. This prevents heat building up and overloading the air conditioning.

The visible part of most small buildings is built from facing bricks. The best facing bricks are made from solid clay in a traditional kiln, which gives them an attractive rich colour. Cheaper facing bricks are now made much like flettons, but their sides and edges are covered with sand which is fused into the clay at a high temperature. These sand-faced bricks do not look as handsome as traditional bricks but they are much cheaper.

Re-cycled ash

All modern houses must have insulated walls and brick is a good conductor of heat, so it is a bad

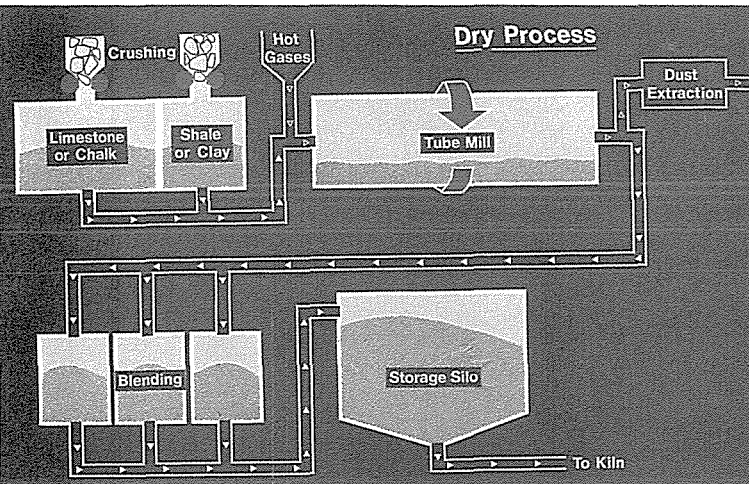


Cement kilns are tilted at 20 degrees to the horizontal. Raw materials are fed in at one end and the kiln revolves slowly, tumbling them through the hot zone where the temperature reaches 1400°C. Clinker (ash) is removed at the other end, then ground into a fine powder ready for use.

British Cement Association

THE UNIVERSAL BEAM

Universal beams are so called because of the huge variety of jobs that they can be used for. Looked at from one end, the beam is 'I' shaped: the central vertical piece of steel is called the web, while the horizontal cross pieces are known as flanges. When used to support a wall or a ceiling the weight 'sits' on the flange, but the deep web supplies most of the strength. If really heavy weights are to be supported, a beam with a web that is three times the size of the flanges is generally used.



British Cement Association

Cement plants are built close to the quarries that supply their raw materials. In the modern 'Dry Process', the raw materials are crushed, dried with the exhaust gases of the kiln, then fed into a tube mill; here they are powdered ready to be mixed to a set chemical composition before being loaded into the kiln.

insulator. So in most houses and many other buildings, the inner part of the outer walls is made from lightweight insulating blocks. Ten or twenty times larger than bricks, these are much cheaper to buy and can be laid much more quickly. The building blocks are made from cement mixed with the ash from coal-fired power stations – a good way of re-cycling spent materials – and are light grey or blue in colour. As they are not waterproof, they are not at all suitable for the outside of buildings.

All types of concrete are made by mixing sand and stone with cement and water to form a 'porridge'. The cement acts as a hardening agent. The initial strength is developed in the first week, but concrete goes on getting stronger over the next 40 years.

Experiments have been undertaken with 'high alumina' concrete

which sets very quickly and reaches maximum strength in a matter of days. Unfortunately, the alumina remains active after the concrete has set and reacts with the silica in the concrete. This can weaken beams and cause them to collapse. Research is continuing, with the main object of combining the advantages of high alumina and conventional concrete.

Structural steel is made in many different shapes and sizes, but the best-known form is the girder or Rolled Steel Joist (RSJ) – officially known as a Universal Beam. These make up the basic structure and supply all the strength in steel-framed buildings. Concrete is used for the floor slab at ground level and to form the ceilings. Unless reinforced, it does not contribute any strength. Universal beams are also used to build pre-fabricated structures, such as out-of-town super-

Concrete is a mixture of cement, water and stones, plus a detergent to make it easier to lay. Concrete is usually mixed at a specialist plant (where the materials can be carefully measured out), then delivered by a mixer lorry, poured into position and spread by hand or machine. Samples taken from each batch are tested for strength at a laboratory.

Structural steel is made in a large number of different sections; I-shaped girders (or Universal beams) are the most common. They are produced by passing hot steel through a pair of rollers powered by electric motors. Each roller has a special profile which shapes the steel.

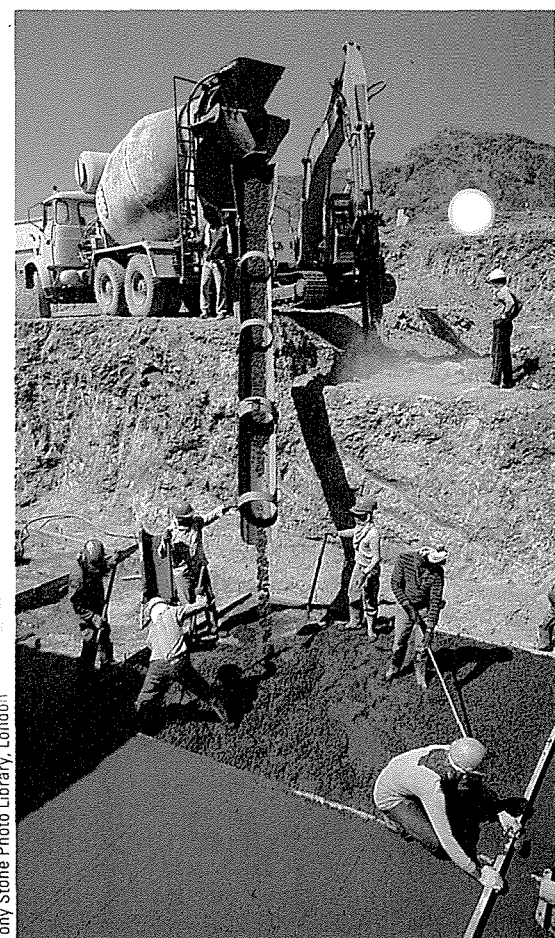
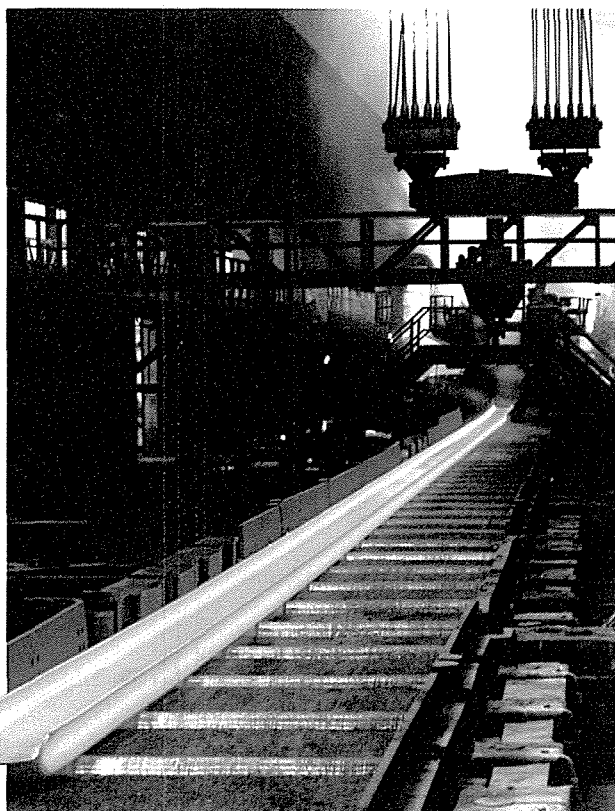
markets, and large installations including aircraft hangers.

Girders may be joined together with large bolts, or they can be welded. A welded joint is made by passing a strong electric current down an iron rod so that the steel of the girder and the welding rod both melt. The molten metal forms a pool and, when the weld is correctly made, the crystalline structure of the metal reforms when the joint cools. This makes a very strong joint that extends the whole depth of the metal. Because a basic steel frame can be erected much more quickly than a concrete one, more steel-framed buildings are being built than re-inforced concrete ones.

● Natural materials

Timber is the only building material that grows rather than being dug out of the ground. It is a renewable resource – and very cheap compared with other structural materials such as steel. Timber is also very easy to cut and shape using simple tools; in addition it can be

British Steel



Tony Stone Photo Library, London

carved and sculpted without seriously affecting its structural properties.

Wood was probably the first building material used by mankind, but it still competes very successfully against modern manufactured products. It can do so because the timber producers have developed a



London Brick Company

George Wimpey PLC

TODAY'S MATERIALS

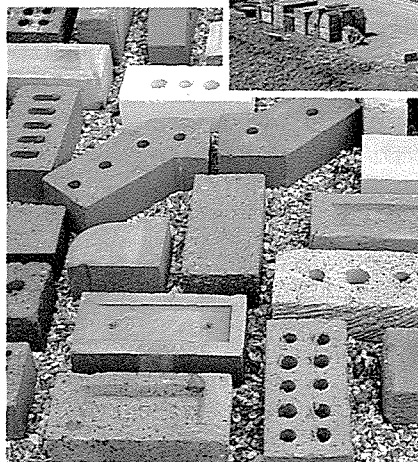
Structural steel can now be rolled into circles and curves, without sacrificing strength, using a special grade of steel that does not crack during the bending process. This type of structure is usually covered with curved glass and looks like a giant conservatory.

Hoffmann kilns are used to bake London bricks, (or Flettons, as they are also called). The bricks are moulded by machine and taken through the kiln on a continuous conveyor. The kiln can be fired for weeks before the fireproof lining has to be renewed.



variety of treatments for raw timber from the forest. Instead of simply using chunks of rough timber, wood is now processed into a variety of products that give guaranteed performance and have a long life in the same way as any other modern material.

The commonest structural timbers are the joists that support floors and ceilings, and the rafters that support roofs in small and medium – sized houses. When logs have been converted into useable sizes and grades of timber at the sawmill, the strength of each piece is tested on a hydraulic machine. If the length of timber does not break when the load is applied, it is labelled to show that it has been 'stress-graded'. Architects can then rely on it to support a certain weight without snapping.



Semi-engineering bricks are hard and waterproof. They are used underground, or to support an extra-heavy load. The holes get filled with cement during laying, giving extra sticking power.

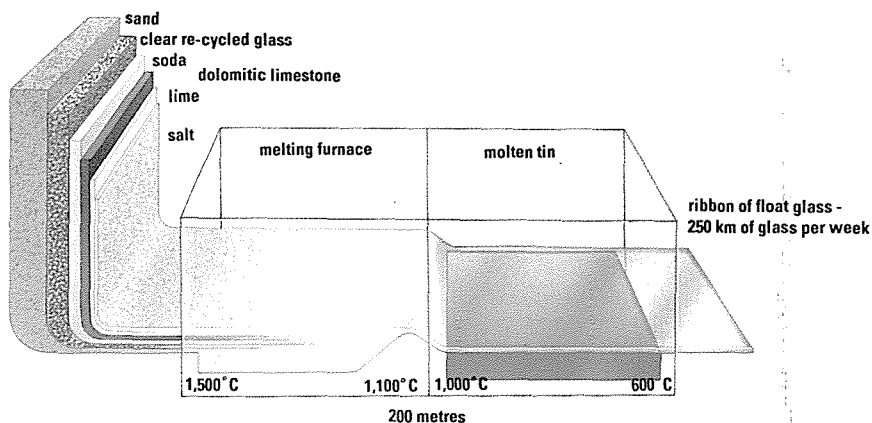
other. This produces a material of enormous strength that can be used either on its own or to reinforce other forms of timber at points of stress as in timber-framed houses, for example.

Two different types of timber are used in construction – softwood and hardwood. Softwood is liable to rot and to be eaten by insects, so it is nearly always treated with preservatives. This can be done

Steam presses

Composite materials built up from artificial fibres are now very common. Plywood was the first product of this type. It is built up from thin layers of wood which are glued together in giant, steam-heated presses. The sheets are laid so that the fibres of wood in adjoining sheets run at right angles to each

Float glass is made in the normal way, but at 1000°C the glass is floated on top of a 'bath' of molten tin. It comes off the end of the bath in a continuous ribbon, then passes into the cooling area.

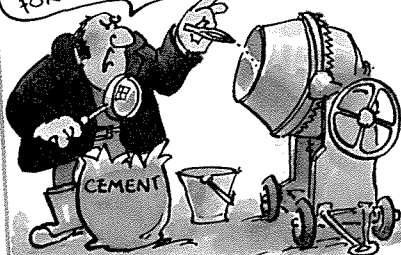


Just amazing!

FINER THAN DUST

IN EVERY KG OF CEMENT, THERE ARE 50 MILLION MILLION SEPARATE PARTICLES. THE SURFACE AREA IN ONE 50 KG BAG TOTALS 17,500 SQUARE METRES – ROUGHLY FOUR FOOTBALL PITCHES.

FORTY EIGHT MILLION AND ONE, FORTY EIGHT MILLION AND TWO...



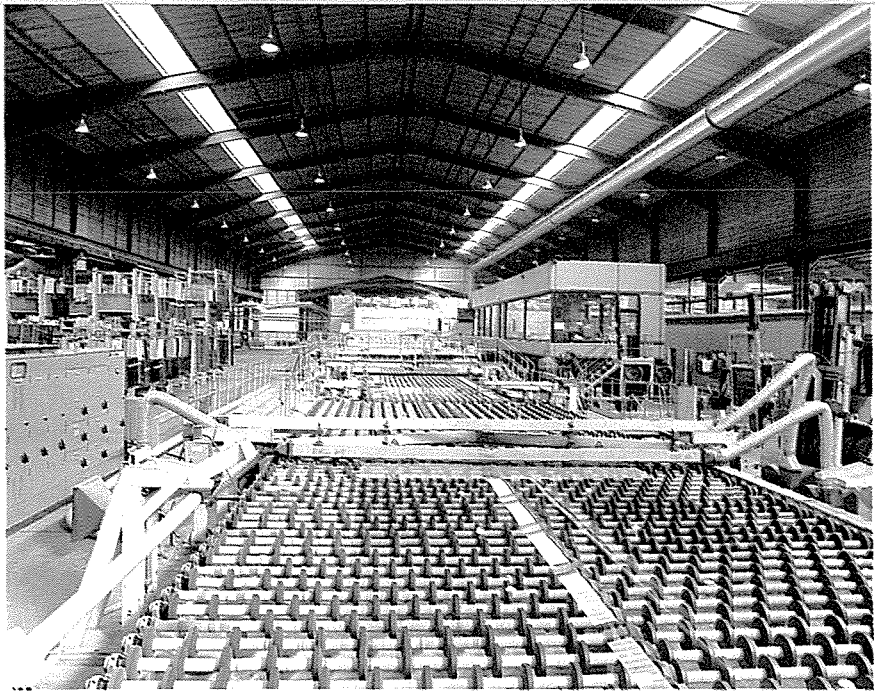
Paul Raymond

GLASS IS SUPERCOOL

Glass is made by melting sand, washing soda and other minerals in a furnace at around 1000°C. When it cools down, glass does not solidify in the same way as most materials. Instead, it acts as a 'supercooled' liquid: it appears solid, but behaves like a liquid. This shows up in old glass windows – the glass flows very slowly to the bottom of the pane, forming perceptible ripples that distort the view.



Graham Moore/Hickson Publicity



Pilkington Glass Ltd

The float glass cooling area is a long set of temperature-controlled rollers. This controlled cooling process takes about 30 minutes and is very important because it takes out the stresses that are set up in the glass during the manufacturing process. Computers instruct cutting machines on how to cut the cooled glass to avoid any waste.

chosen as the filler because they are cheap and they give a traditional appearance to a high technology structure. Factory-made cladding is preferred when the architect wants a hi-tech look.

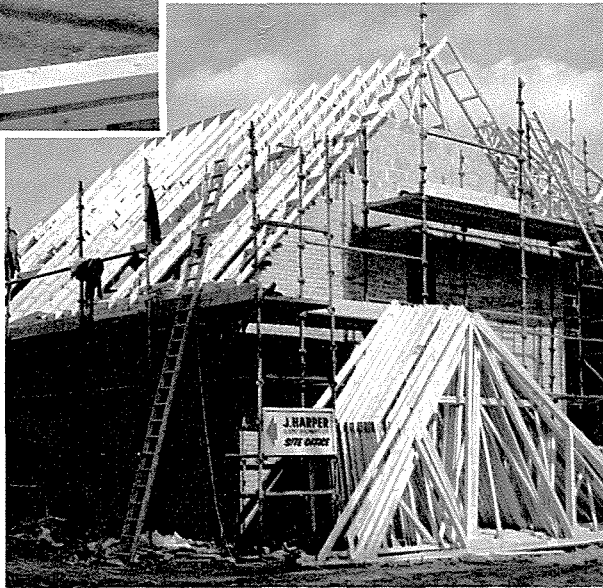
Thin panels of steel or aluminium, coated with epoxy paint at the factory, are a cheap and long lasting form of cladding that can be quickly fixed to the framework. Another cladding system uses sheets of reconstituted marble that look very natural, even though the sheets are made in a factory. However, plate glass is probably the cheapest and longest-lasting cladding.

● Glass cladding

Glass used for cladding is plate glass quality – almost perfectly flat on both sides and both sides are also exactly parallel, so there is very little optical distortion.

The float glass process can also be used to process normal, clear glass into a variety of other types. The best known of these is reflective, or solar control, glass. The mirrored outer surface of the glass reflects the sun's rays, preventing a build-up of heat inside. However, it doesn't prevent the occupants of the building from seeing through the windows as normal.

Roof timbers are computer-designed and factory-assembled into roof trusses. As thin timber is used, the joints are re-inforced with plywood or steel spreader plates. On site (right), the trusses are lifted into place with cranes and a complete roof can be fixed in a day.



Graham Moore/Hickson Publicity

after the wood has been used, but the chemicals involved are unpleasant and it is sometimes impossible to ensure full coverage.

Better coverage can be obtained by enclosing the timber in a vacuum chamber, and then applying the preservative which will penetrate every cell. Wood treated in this way is guaranteed to last at least 60 years when used according to instructions.

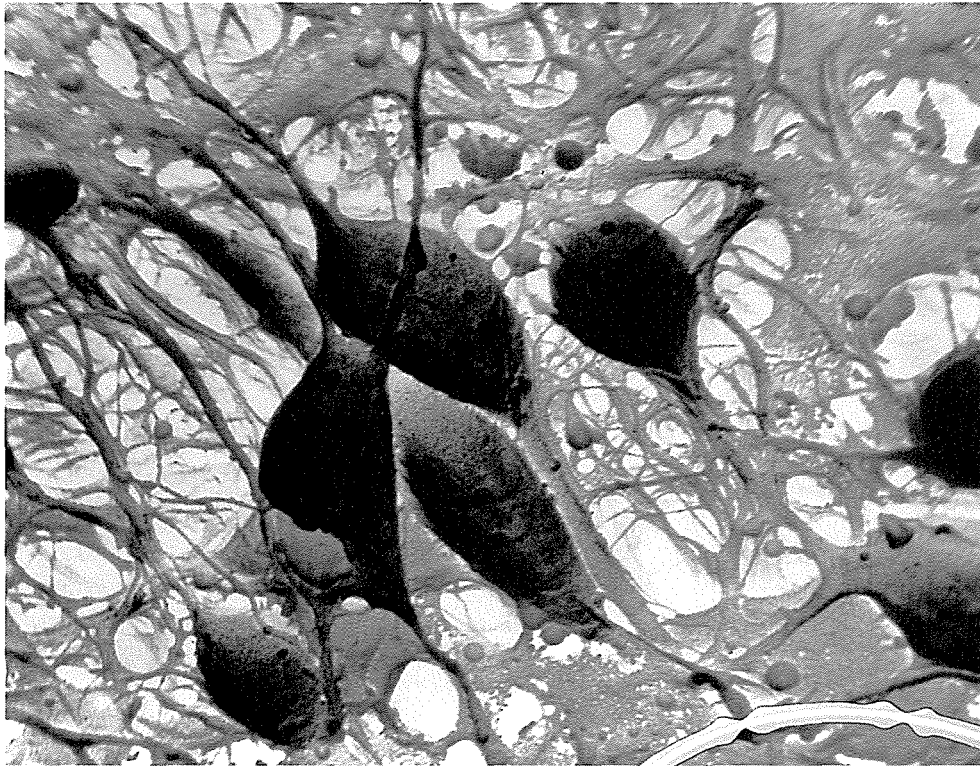
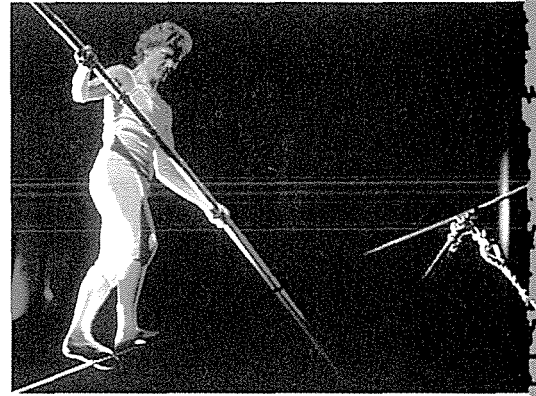
Now that the main strength of many buildings is provided by a steel or concrete frame, materials that fill the gaps between the structural elements do not have to take any weight. Bricks are often

Traditional Japanese houses have a wooden structure. The walls may also be made of wood, but reeds are often preferred because they give insulation against the cold. The windows are filled with oiled paper, not glass. Inside the house, sliding partitions are used instead of fixed walls so that the living area can be divided up into bedrooms at night.



Japanese National Tourist Organization

MIND AND BODY

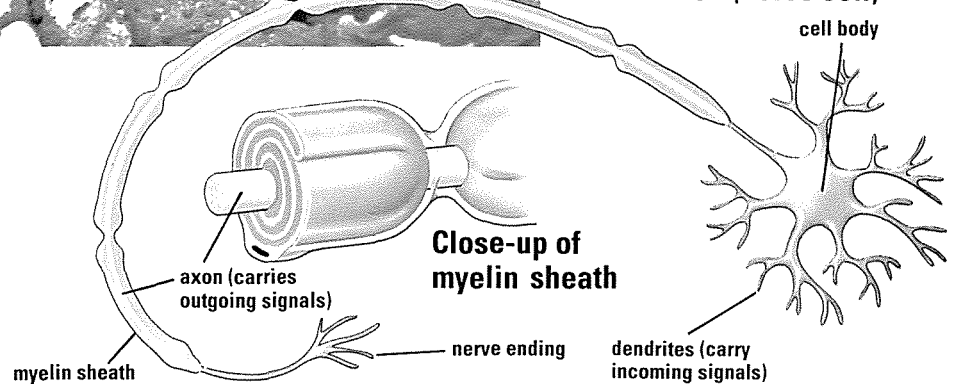


Special areas of the brain automatically control skills such as balance, leaving other areas free to carry out conscious actions.

Nerve cells (neurons) carry electrical signals. Some take messages from sense organs, such as the tongue or eye, and pass them to the brain or spinal cord. Others pass messages from the brain or spinal cord to muscles and glands. Each cell has a rounded body with many fine fibres, plus a single long fibre, called the axon.

Axons carry signals away from the body of the neuron to the fine fibres (dendrites) of other nerve cells. Axons with a fatty coat of myelin transmit impulses faster than those without one.

The neuron (nerve cell)



NERVOUS SYSTEMS

REFLEX ACTIONS

BRAIN STRUCTURE

THE DOMINANT POSITION OF the human race on the Earth is due entirely to its highly developed brain. The brain consists of a mass of specialized nerve cells (or neurons) together with many other cells that support and nourish the neurons. The brain is thus a major part of the nervous system – a communication network that links all parts of the body.

The nervous system has two main parts. The central nervous system (CNS) consists of the brain and the spinal cord. The peripheral nervous system (PNS) includes all the nerves running to and from the CNS.

The fundamental unit of the nervous system is the neuron. It is

generally believed that all the neurons in the CNS are present at birth and grow as the infant grows. Unlike most cells in the body, neurons do not reproduce themselves and, once lost through injury or disease, are gone forever.

A typical neuron has three parts. The *cell body* makes the chemicals needed for the neuron's working. Short fibres known as *dendrites* extend from the cell body. They carry nerve impulses towards the cell body. A very long extension of the cell, the *axon*, carries the nerve impulse away from the cell body and on to other neurons.

In one type of nerve the axon is encased in a fatty sheath made of a substance called myelin. Nerve impulses are conducted very quickly along these axons – at speeds of up to 400 km/h. Impulses travel more slowly along nerve fibres that do not have myelin sheaths.

At its far end, the axon divides into branches, each ending in a number of tiny knobs. Each knob is very close to, but not actually touching, a dendrite from another neuron. This gap is called a *synapse*, and messages are transmitted across it.

Nerve fibres are of two major

types: *motor fibres*, which carry impulses from the central nervous system to muscles; and *sensory fibres*, which carry impulses from sense organs, such as the taste buds in the tongue, to the CNS.

The main parts of the peripheral nervous system are *nerves*, which connect the central nervous system to all other parts of the body, and *ganglia* — groups of nerve cells located at various points. A nerve is a bundle of motor and sensory fibres, together with other tissue and blood vessels. There are 43 pairs of major nerves: 12 pairs emerge from the underside of the brain (the cranial nerves) and 31

Reflexes such as the knee-jerk response are controlled by the spinal cord. Good responses show the nerves are working well.



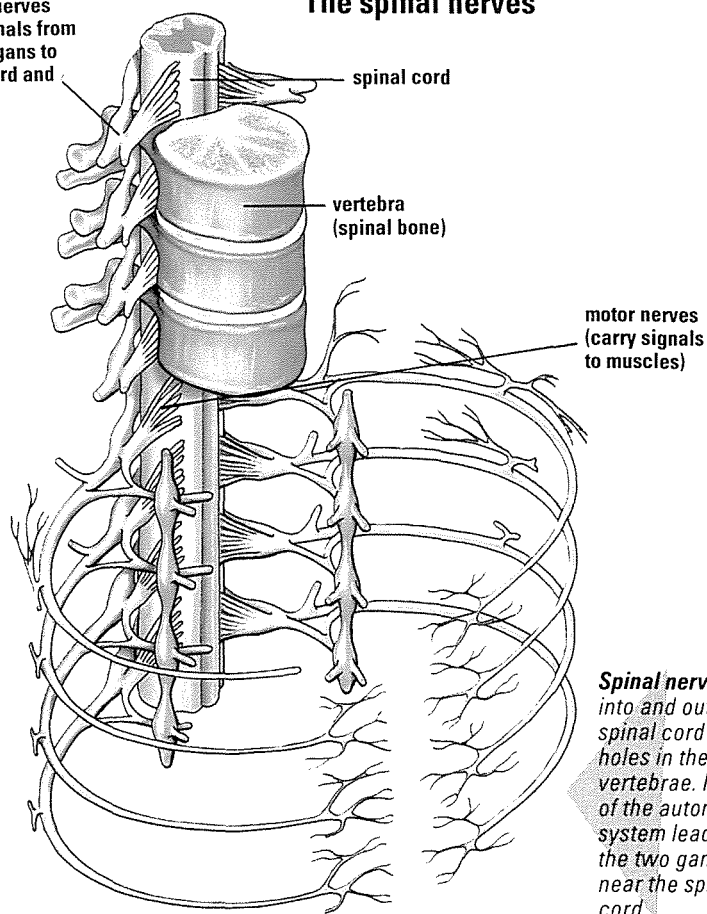
Jerry Mason/SPL

pairs from the spinal cord (spinal nerves).

The cranial nerves mainly go to sense organs and muscles in the head. But one very important cranial nerve, called the vagus, goes to the digestive organs, to the heart and to air passages in the lungs.

Some cranial nerves, such as the

The spinal nerves



Spinal nerves pass into and out of the spinal cord through holes in the vertebrae. Nerves of the autonomic system lead from the two ganglia near the spinal cord.

BRAINWAVES

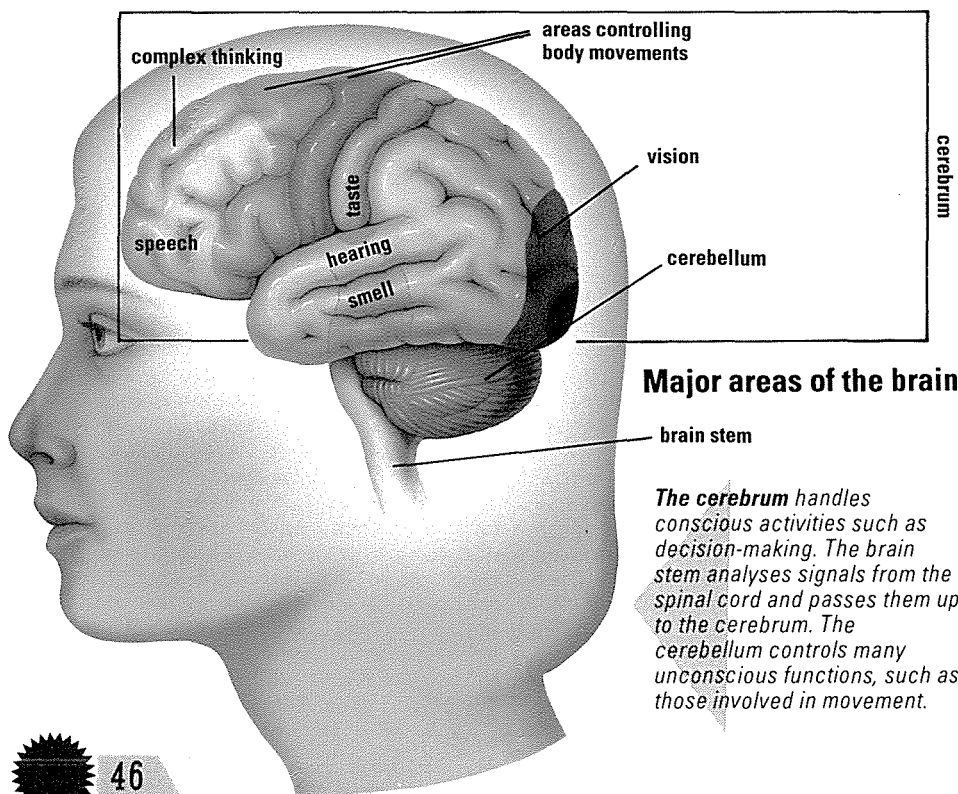
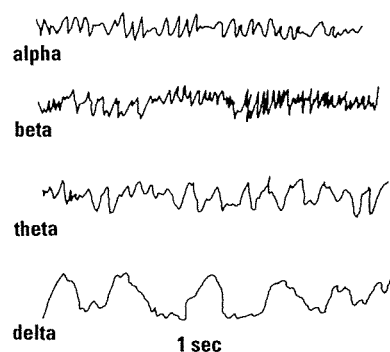
The rhythmic electrical voltages produced by the brain are measured with an electroencephalograph (EEG). They provide clues to the brain's activity. If they are too fast or too slow, there is something wrong with the subject's brain.

Alpha waves about 10-12 cycles per second. They dominate the brainwaves when the person is relaxed. They disappear during sleep.

Beta waves 15-60 cycles per second. They appear when the person is sedated.

Theta waves 5-8 cycles per second. They occur during drowsiness and in light sleep, replacing alpha waves.

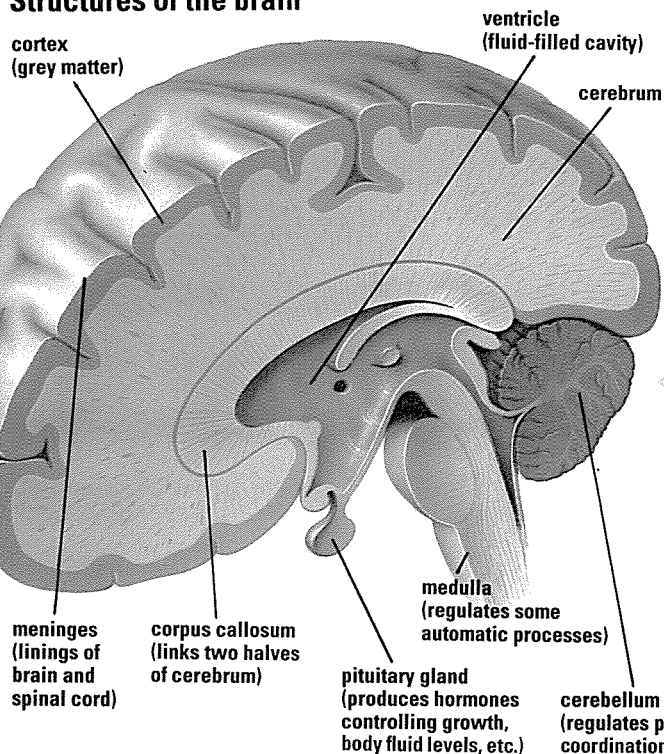
Delta waves 1-5 cycles per second. These large waves occur during deep sleep in adults, but all the time in infants.



Major areas of the brain

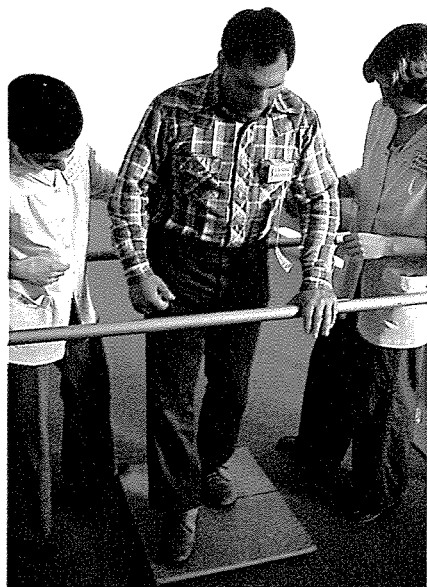
The cerebrum handles conscious activities such as decision-making. The brain stem analyses signals from the spinal cord and passes them up to the cerebrum. The cerebellum controls many unconscious functions, such as those involved in movement.

Structures of the brain



The cortex, a 3 mm thick layer of 'grey matter', is where data from the senses is processed. It is the outer 'skin' of the cerebrum, which is in two linked halves, or hemispheres. The medulla regulates some automatic processes, such as breathing and simple reflexes. The pituitary gland's hormones regulate growth, the reproductive cycle and other glands, while the cerebellum co-ordinates movements.

A stroke victim gradually regains his reflexes through gentle exercise. Strokes are due to a failure of the brain's blood supply.



Josephus Daniels/SPL

tor cells. It transmits signals along motor fibres from the central nervous system to the muscles, so that we can carry out movements of our bodies.

The autonomic system is mainly concerned with keeping up the automatic functions of organs such as the heart, lungs, stomach, intestine, bladder, sex organs and blood vessels, without deliberate mental or other effort on our part. It consists entirely of motor nerves arranged in relays from the spinal cord to the various muscles.

Sympathetic systems

The autonomic nervous system has two parts, known as the *sympathetic* and *parasympathetic* systems. They have different effects on the organs they serve. For example, parasympathetic nerves make the airways leading to and from the lungs constrict (grow narrow). The sympathetic nerves serving the same areas cause the airways to widen. In general, the sympathetic system arouses bodily organs, preparing them for 'fight or flight'. The parasympathetic system has the opposite effects on those organs.

The whole of the autonomic system is controlled by an area of the brain called hypothalamus. This receives information about any variations in, for instance, the body's chemical make-up and adjusts the autonomic system to bring the body back to the right balance. For example, if oxygen in the tissues is used up during exercise, the hypothalamus instructs the autonomic nervous system to increase the heart rate in order to supply more oxygenated blood.

The peripheral nervous system relays sensory and motor messages between the central nervous sys-

tem and the body's muscles, glands and sense organs. It does not analyse sensory signals or initiate motor signals. Both these activities, and much else besides, occur in the central nervous system – the brain and spinal cord.

The spinal cord is a roughly cylindrical column of nerve tissues, about 40 cm long in an adult, that runs inside the backbone from the brain to the lower back. It contains *descending* nerves, which send motor impulses from the brain to the peripheral nervous system, and *ascending* nerves, which channel sensory impulses to the brain.

Nerve fibres extend in long bundles from parts of the brain. They run varying distances down the spinal cord. At the ends farthest from the brain they come into contact with the fibres or cell bodies of sensory and motor neurons belonging to the peripheral nervous system. Messages can be transmitted across the synapses, between the peripheral neurons and the spinal neurons.

The spinal cord controls simple reflex actions. This is achieved by neurons whose fibres extend short distances up and down the spinal cord, and by interneurons, which relay messages directly between the sensory and motor neurons.

If, for example, you accidentally put your hand on a hot stove, pain receptors in the skin send messages along sensory fibres to the spinal cord. Some of these messages are relayed immediately by neurons to motor neurons that control the movements of the arms and hand muscles, so the hand is quickly – and automatically – withdrawn. Other messages travel up the spinal cord and are relayed by interneurons to the motor neurons that control the neck's movements. As a result, the head is automatically

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Reflex movements

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Just amazing!
BIG-HEAD!
DURING THE AVERAGE PERSON'S LIFETIME THE NEURON NETWORK IN HIS OR HER BRAIN WILL STORE ABOUT 1,000 MILLION MILLION BITS OF INFORMATION.



Paul Raymond

turned towards the source of the pain. Further messages are carried all the way up to the brain, where they cause the conscious sensations of heat and pain.

● The brain

Basically the brain can be divided into three different regions; hind-brain, midbrain and forebrain. Each of these regions is in turn divided into separate areas.

The cerebellum is the largest structure in the hindbrain. It is the area that is mainly concerned with motor activities. It sends out signals that produce movements in muscles so that posture and balance are



The hypothalamus is concerned with the control of vital functions such as eating, sleeping and temperature control. It lies at the base of the brain, under the cerebrum. It is immediately below the thalamus, which acts as a telephone exchange between the spinal cord and the cerebrum.

The cerebrum is the largest part of the forebrain. It is more developed in humans than in any other animal and is essential for thought, memory, consciousness and complex thought processes. This is where the other parts of the brain send incoming messages for a decision. It is divided into two halves, called 'hemispheres'. Each specializes in certain tasks. Usually the left hemisphere deals with language, while the right handles musical and artistic activity.

The basal ganglia lie at the centre of the cerebral hemispheres. They are a mass of 'grey matter', which is mostly made up of nerve cell bodies. These cells form a complex control system that co-ordinates muscle activity and allows a person to perform specific types of movement without conscious thought.

The cerebral cortex is the wrinkled layer of grey matter, 3 mm thick, folded over the outside of the cerebrum. This part of the brain has become so highly developed in humans that it has had to fold over and over in order to fit inside the skull. Unfolded, it would cover an area 30 times as large.

The living brain can be revealed by the technique of NMR (nuclear magnetic resonance). This image of a child's brain clearly shows the folds of the cortex, the spinal cord and the cerebellum (lower rear of the brain).



maintained. It also works with the motor areas of the cerebrum to co-ordinate movements.

The brain stem links the brain with the spinal cord. It comprises part of the hindbrain, all of the midbrain and part of the forebrain. It is here that all incoming and outgoing messages come together and cross over (the left side of the body is governed by the right-hand side of the brain and vice versa).

The various structures in the brain stem, including the medulla and the reticular activating system, control heart rate, blood pressure, swallowing, coughing, breathing and unconsciousness.

An NMR scanner surrounds the head of the patient. A pulsed magnetic field causes atoms in body tissues to send out radio waves. A computer builds the signals into an image.

Medicines are tested on animals before they are used for humans. A tube has been fitted into this monkey's skull so drugs can be passed into its brain.



National Anti-Vivisection Society

METAL ALLOYS

FOILING FORGERS

PLASTIC BANKNOTES

MINTING & PRINTING

COINS AND BANKNOTES ARE still very much in demand, despite the growing popularity of cheques and credit cards. So banknote printers have to take a lot of trouble to deter people from forging paper money.

But most coins are worth so little these days that crooks no longer bother faking them.

Different countries use different metals for their coins. In Britain, Ireland, Australia and New Zealand, for instance, the 'copper' coins are made of bronze, while the 'silver' coins are made of a metal called cupronickel. In the USA, traditional copper cents have been replaced by copper-plated zinc coins, and the silver dollars by cupronickel ones.

Bronze and cupronickel are alloys — mixtures of metals rather than

Finished coins are washed and dried in the top drum, then poured into the hopper of the counting machine. Printed notes (inset below) are counted automatically.



Royal Mint

George Bernard Science Photo Library



Philadelphia Mint, in the USA, is the largest in the world, producing 8 billion coins a year. To cope with the very high production speeds, coinage metal is fed into the blanking machine from continuous coils. After minting, the coins go through the quality control stage (inset below). Sample coins are weighed and a few, chosen at random, are given a visual inspection using a magnifying glass.



pure ones. The exact proportions of each metal in the alloy are carefully chosen so that the final coins will look right – many countries still want their coins to look like silver or gold – and be hard-wearing.

Coinage bronze consists of around 97 per cent copper, 2.5 per cent zinc and 0.5 per cent tin. Cupronickel contains around 80 per cent copper and 20 per cent nickel. Many high value coins that look like gold are made of 70 per cent copper, 5 per cent nickel and 25 per cent zinc.

Minting coins

The first stage in minting coins is to produce the metal. The pure metals, such as copper, zinc and tin, are melted together in a small electric furnace in the correct proportions to make the alloy for the coins.

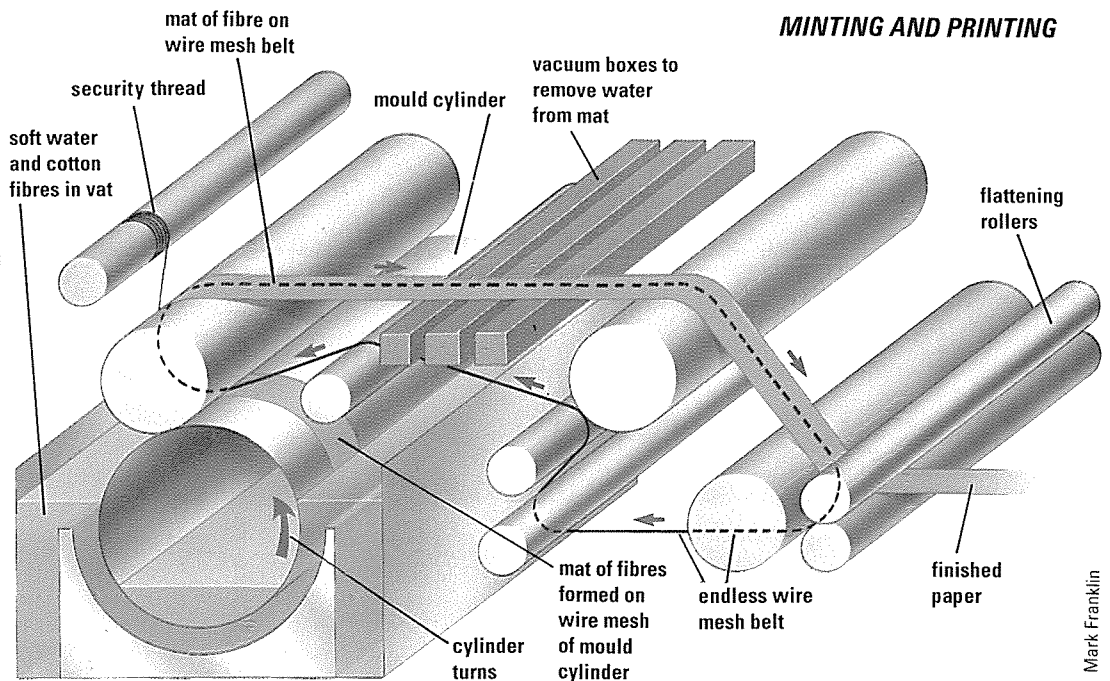
When the furnace is tapped, the alloy is cast into slabs about 210 mm wide and 13–19 mm thick.



Coin dies carry the design in reverse so that the finished coin reads correctly. Many sets of dies are fitted to the minting machine (below). The dies are carried round from the magazine where the blanks are loaded to striking and infra-red inspection positions.



Banknote paper is made on a machine 200 metres long. The wet cotton fibres are picked up on the mesh surface of the mould cylinder as it revolves in a vat of water and fibres. The mat of wet fibres is transferred to a wire mesh belt where some water drains off. Next, it passes through rollers, which flatten and polish the surface, before it is dried.



Metal security strips can be added to the wet paper while it is still clinging to the mould cylinder. The latest 'window' strips are difficult to forge.

Watermarks are made while the fibres are on the mould cylinder. The design is picked up from patterns on the wire mesh surface.



Old denim jeans, worn out vests and all sorts of other cotton rags are used to make banknote paper. The rags are broken down into fibres with powerful chemicals and are carried to the paper-making machines on water.



which has the design of one side of the coin cut into it.

On the minting machine, a blank is automatically placed on the bottom die and held in place by a collar. The inside of the collar carries the design, if any, that will appear around the edge of the finished coin.

With the blank in place between them, the two dies are squeezed together in a hydraulic press using a force of up to 150 tonnes. This force is so great that the metal

almost melts for a moment. The pressure forces the metal outwards so it fills the die completely and the rim picks up the shape and design on the inside of the retaining collar.

Next, the dies open and the coin is automatically ejected. A fresh blank is then inserted and the process starts again. The working life of a set of steel dies (which may operate at speeds of up to 600 coins a minute) is about 200,000 coins.

The Royal Mint at Llantrisant, South Wales, produces all the coins for the United Kingdom, as well as making coins and medals for 60 overseas countries. The United States has two separate mints, one in Philadelphia, Pennsylvania and the other one at Denver, Colorado.

Banknotes

When the first colour photocopiers came out, the thought of getting rich by photocopying money probably crossed the minds of many people. However, early colour photocopies were not good enough to fool anyone, and the law takes a dim view of that sort of thing – forgers usually get locked away for years.

In fact, the banks that issue banknotes take great care to ensure that forging them is extremely difficult and expensive. The three main things about banknotes that make them hard to fake are: the special paper that is used, the complicated

printing processes involved and the intricate designs. New technologies, such as making banknotes from plastic instead of paper, will make life even more difficult for forgers in the future.

There is just one company in the world that specializes in making banknote paper and it only supplies the paper to authorized banknote printers – for obvious reasons. While the paper is being made, two additional anti-forgery features can be added if required.

One is the watermark – these are formed on the papermaking machine. A wire mesh leaves a translucent design in the fibres of the paper while it is still wet. To find the watermark, look for a blank patch in the design; hold the note up to the light and you will see the watermark inside the blank patch. The other anti-forgery feature is a thin metal strip called a security thread, which is sometimes embedded in the paper.

Hand engraving

The printed design on a banknote is usually a complicated mixture of portraits, pictures and geometric

Just amazing!

MONEY TO BURN

THE CENTRAL HEATING AT THE BANK OF ENGLAND PRINTING WORKS IS FIRED BY BURNING OLD BANK NOTES THAT HAVE BEEN WITHDRAWN FROM USE. AT LEAST 4 MILLION OF THEM ARE BURNT EVERY WORKING DAY.

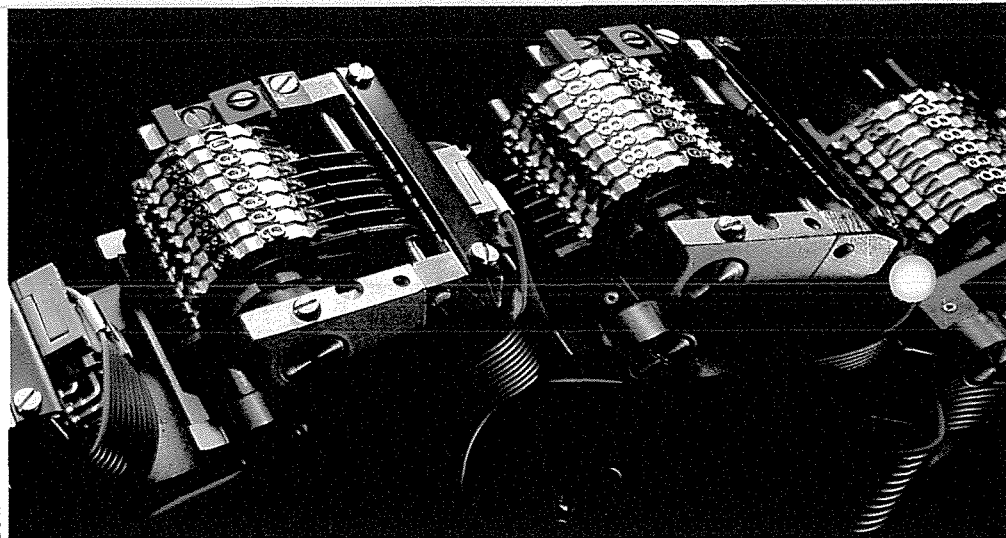


Paul Raymond

patterns. Much of the design work is done by computer-aided design (CAD) equipment, but the main portraits are hand-drawn by artists, then transferred to a steel block by a highly-skilled engraver.

The engraving is made by cutting lines into a block of steel and is done entirely by hand. It can take many months to produce the engraving of a single portrait and the detail is so fine the engraver has to use a microscope to see it. The tools used are very similar to lino-cutting tools.

The master copy of the design is then transferred to the printing



Numbering heads are used to print the serial numbers on notes. The numbers change automatically after printing each note. They also trigger an electronic read-out which counts the number of notes printed.

Geometric background patterns are engraved on the printing plates using a computer-controlled machine that puts in random variations. The irregularity of the final pattern is difficult for forgers to copy.

The main portraits are printed afterwards, by a process called intaglio, and the image is sunk into the surface of the printing plate. Thick printing ink is spread across the plate and the surplus is then removed using a thin steel blade that scrapes the surface. This leaves ink in the fine grooves. The paper passes through rollers that press the paper into the grooves.

The paper picks up the ink, forming printed lines that are slightly raised above the surface of the paper. If you take a new banknote and rub it lightly between your thumb and forefinger, you can feel the raised printing.

One way to make banknotes last longer would be to make them out of plastic rather than paper. This has been done in Australia, where the first plastic note was issued in 1988. These notes are equipped with a new type of anti-forgery feature that looks like a hologram.

FOILING THE FORGERS

Laser copiers now produce excellent copies in full colour. What is more, they can be programmed to modify the output until the copies exactly match.

Forgers soon spotted that one of these laser copiers would produce excellent forged banknotes, without the trouble of engraving printing plates. To counter this threat, special fluorescent inks are now being used to print banknotes. These inks produce a bright light when examined in a special cabinet under ultraviolet light. The cabinets allow bank employees and the police to examine the notes without any danger of skin burns from the light.

A Canadian team has developed a way of making very thin, transparent strips of zirconium dioxide. These will be stuck on banknotes and show brightly-coloured patterns when looked at from an angle.



plates, which are often chrome-plated to give them a very long life on the printing press.

Banknote printing involves a combination of printing methods – something else that makes forgery difficult. The background designs are usually printed on a specially-modified offset litho newspaper press. The ink is transferred to the paper by a springy rubber blanket.

Plastic Australian banknotes feel similar to paper ones but last much longer. They have an **Optically Variable Device (OVD)** in the top right hand corner to deter forgers. Printing on the plastic is difficult.



BLACK GOLD

FOSSIL FUEL

OIL EQUALS MONEY FOR most of the world today. Any change in the price of oil has an enormous impact on the economies of nations which, in turn, will affect everyone's lives.

Crude oil is a complicated mixture of hydrocarbons — compounds made up of carbon and hydrogen. From it, we get the fuels for our cars, trucks, planes and diesel trains, and we use it to heat buildings and generate electricity. It also provides the raw materials from which we make an enormous range of goods, including chemicals, plastics, detergents, waxes, paints and dyes, adhesives, explosives and medicines.

This source of energy we take so much for granted is the product of millions of years of evolution. The remains of plants and tiny animals settled at the bottom of prehistoric seas and were gradually covered with thick layers of mud. Over many thousands of years, the mud hardened into rock and the plant and animal remains beneath it decomposed into the thick, black liquid we know as petroleum, or crude oil.

OPEC

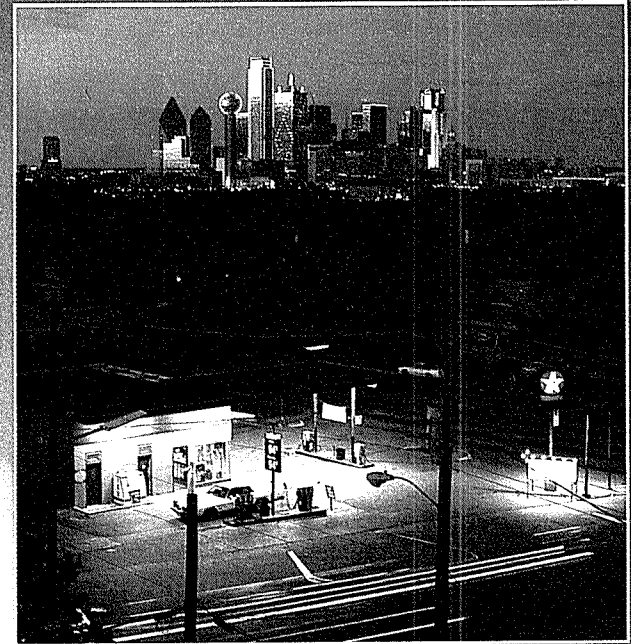
Oil is an essential commodity. Any shortages, or increases in its price, can make oil producers richer and their customers poorer.

Black money

Oil is priced in US dollars per barrel: a barrel of oil being 42 US gallons (159 litres). The dollars paid to the producers for their oil are nicknamed 'petrodollars'. With world oil production running at about 65 million barrels a day, there are a lot of petrodollars flowing into the bank accounts of oil-producing countries.

From the end of World War II (in 1945) to the late 1960s, the price of oil was controlled by the major Western oil companies. These oil

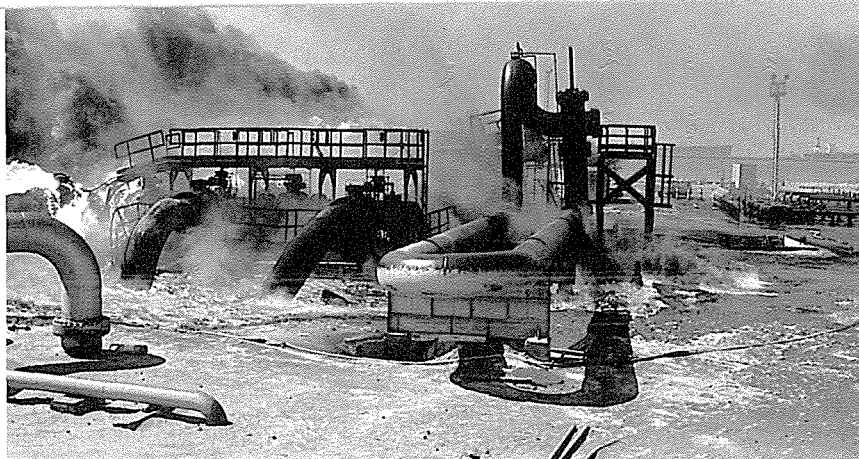
PETRODOLLARS



Tony Stone Photo Library, London

ZEFA

The snowy wastes of Alaska are rich in oil. The USA is the second largest oil producer, but also the leading importer, because petrol consumption is very high (inset above).



An oil refinery south of Kuwait City set alight by Iraqi Troops continues to burn and plunges the area into pitch blackness.

companies were dominated by the so-called Seven Sisters: the American companies Esso, Gulf, Texaco, Mobil and Chevron, BP of Britain and the British-Dutch company, Shell.

During the 1960s, the oil-producing countries began to take more control of their valuable oil resources.

OPEC (Organization of Petroleum Exporting Countries) was set up in 1961 to protect the interests of a group of oil-producing nations, consisting of Iran, Iraq, Kuwait, Saudi Arabia and Venezuela. Since then,

In late 1973, as a retaliatory measure in the Arab-Israeli war, the OPEC members raised the price of their oil from \$3 to \$5.12 a barrel. They also cut back on their oil production, to create a world-wide shortage of oil, which gave them more control over the price throughout the 1970s.

These price increases brought

Millions of litres of oil are carried across the seas by specially built supertankers to the oil hungry nations of the world. However, when oil producers become victims of war, they can cut off vital supplies and sea routes.



Tony Stone Photo Library, London

An ancient culture is reshaped by the sudden and immense wealth brought to many Arab countries by their oil wells. But when Arabs import Western luxuries with petrodollars, they also contribute to the economies of the exporting nations.

huge sums of money to the OPEC countries, in particular to the Arab states and Iran. In effect, this money was being taken out of the Western countries and put into the oil-producing countries, making them, for a time, staggeringly rich.

Oil crisis

A second world oil crisis, much worse than the first, came in 1979. The Iranian oilfields were shut down for a time after the revolution there. This caused a shortage of oil, which pushed the price up to over \$30 a barrel.

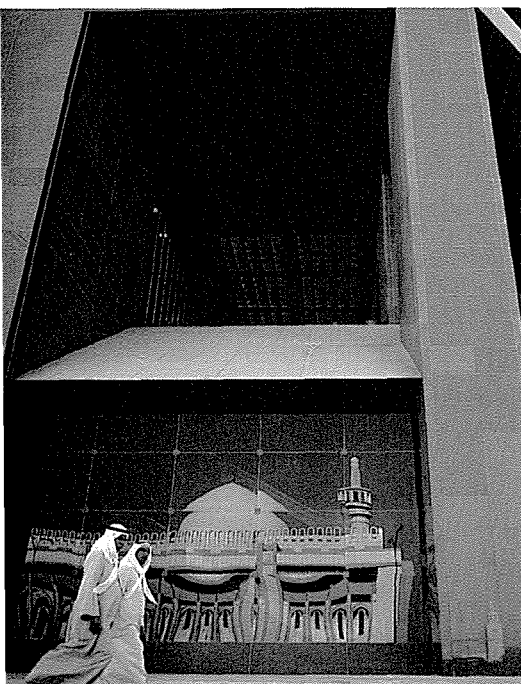
The high oil prices had a bad effect on the already weak industries of the West. The demand for oil fell as factories closed and unemployment rose. In addition, Western countries were finding ways to use less oil. They were also using more coal, natural gas and nuclear power instead of oil.

At about the same time, new oil fields were being developed by non-OPEC countries, such as Mexico, the former Soviet Union, Britain and Norway.

New competition

These factors helped bring the price of oil down, and by 1989, it was only about \$14 a barrel. This was good news for the countries that had to buy oil, but not so good for the producers, including the OPEC countries. The Iran-Iraq War in the 1980s, together with Iraq's invasion of Kuwait in 1990, followed by its subsequent defeat in 1991, further disrupted OPEC production.

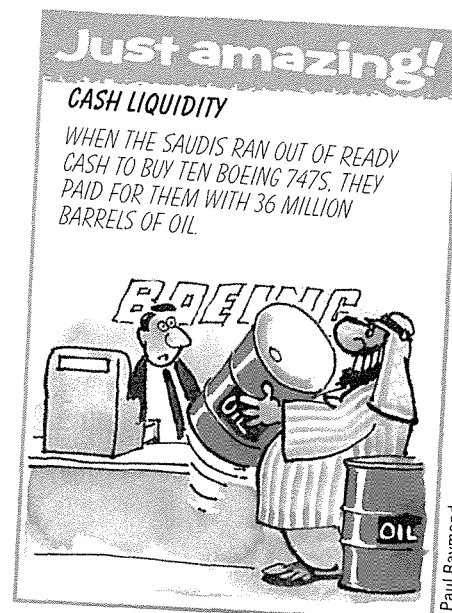
OPEC's share of world oil production fell from around 55 per cent in 1973 to about 40 per cent in 1992. Apart from Saudi Arabia, the world's two largest producers in 1992 were the USA with 13 per cent and Russia with 12.5 per cent of the world total.



Tony Stone Photo Library, London

Algeria, Ecuador, Gabon, Indonesia, Libya, Nigeria, Qatar and the United Arab Emirates have joined them.

In 1970, Libya, led by Colonel Gaddafi, made the oil companies raise the price of its oil and cut back on production. The other OPEC countries soon followed Libya's example and within a couple of years it was OPEC, not the Seven Sisters, that controlled the price of oil.



Paul Raymond

LIGHT ITSELF IS INVISIBLE

— The beam of light you see from a camera flash is only reflection from dust or smoke in the air. It is only when light reflects off objects that we can see it.

— The sun is a ball of fire.

— The moon is a ball of rock.

— The stars are balls of gas.

— The planets are balls of rock.

— The galaxies are balls of stars.

— The universe is a ball of everything.



• MIRRORS AND LENSES

• GAMMA RAYS

• PHOTON POWER

UNDERSTANDING

LIGHT





Alex Barthe/SPL

depends on its wavelength. The shorter the wavelength the higher the energy, the longer the wavelength the lower the energy of the photon.

The electromagnetic spectrum ranges from high energy gamma rays, produced during the decay of radioactive elements, through X-rays, made when electrons are rapidly accelerated or decelerated, to the ultraviolet and visible light, emitted or absorbed when electrons move from one energy level to another within an atom. Beyond visible light there are the infra-red and microwaves, which are also produced by the movement of electrons within atoms and then radio waves,

generated by the rapid oscillation of electrons.

The wavelength of gamma rays and X-rays are the shortest, ranging from 0.0001 nm up to 1 nm (1 nm or nanometre is one thousand millionths of a metre, or 10^{-9} m). The ultraviolet ranges from around 5 nm to 400 nm.

A range of colour

Next comes visible light with the familiar range of colours – violet, indigo, blue, green, yellow, orange and red – whose wavelengths range from 400 nm to 770 nm. Infra-red wavelengths range from 750 nm (0.75 μ m or micrometers) to 1 mm.

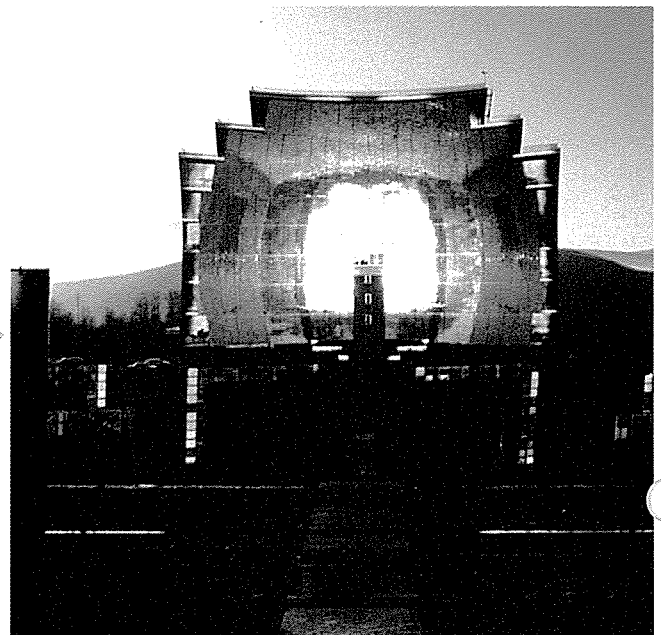
Chlorophyll in the leaves of trees captures the blue and red components of sunlight and chemically converts them into food energy.

Around the turn of this century though, certain atomic phenomena were discovered that could only be explained if light occurs in small, discrete amounts – particles again. It took the genius of Albert Einstein (1879–1955) to propose that light consists of tiny packets of waves, later known as photons. This explains why light behaves like a wave in some ways and as particles in other ways.

The energy of an individual photon

This solar furnace in southern France uses over 180 sq metres of mirrors to focus sunlight. Temperatures of 4,000°C produced can melt up to 3 tonnes of steel at a time.

Visible light forms just one small part of the light spectrum, which extends from high energy gamma rays to low energy radio waves.

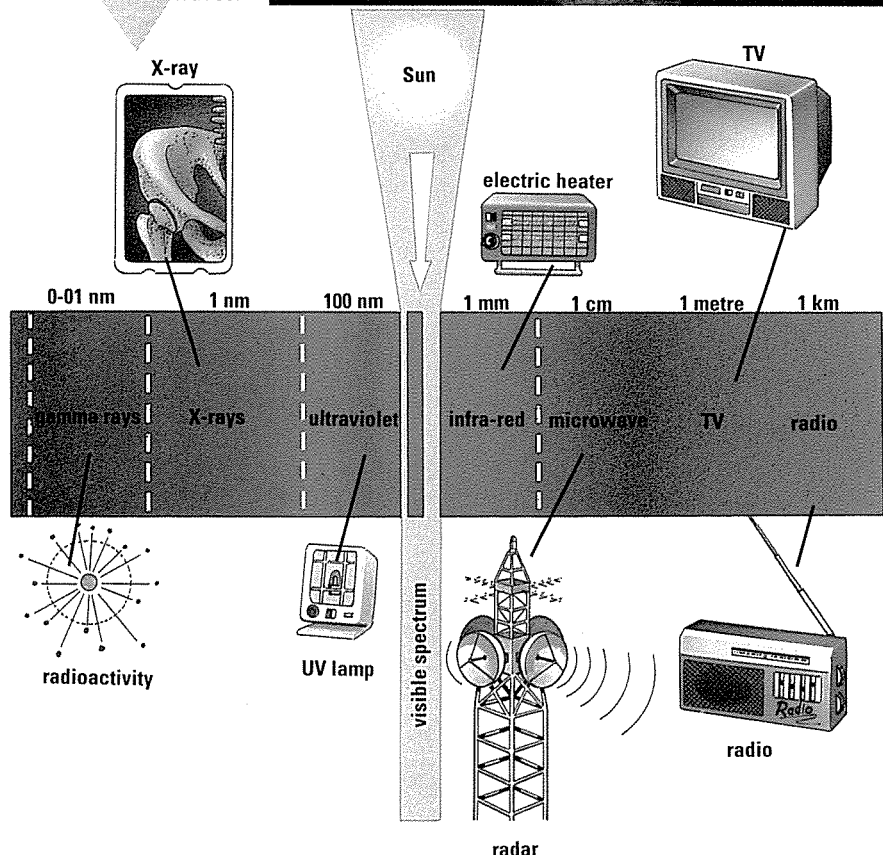


CNRS/SPL



Simon Bruty/Allsport

A solar-powered car takes to the road in Australia. The entire roof of the car is a solar collecting panel.



John Houghton

Microwaves have wavelengths between 1 mm and 3 cm. Radio waves have wavelengths from 3 cm upwards. One of the longest radio wavelengths used for broadcast transmissions is 1500 m on the long waveband of most radios. Even longer wavelength radio transmissions are used to transmit radio signals to submarines when they are underwater. To transmit these signals airdials many hundreds of metres long are needed.

James A Bourdier/Colorific



Sunlight tans the skin – and can cause severe burning (inset below). Some rays penetrate deep into the skin and may cause skin cancers and premature aging.



Bouncing light

Visible light occupies only a tiny part of the electromagnetic spectrum; without modern equipment we are blind to all the other radiation around us.

Light waves travelling through air are reflected back by an ordinary

mirror with a silvered glass back. The image we see in the mirror is known as a 'virtual image' because – unlike the real image of an object – it is formed by the apparent rather than the actual convergence of light rays.

Reflected light bounces off a flat surface at the same angle as it hits it and is also in the same plane. Thus light hitting a mirror at 45° is reflected back at 45° .

The image in a flat mirror is flipped horizontally so that it appears that your left eye is the mirror image's right eye. It is odd to think that in a mirror we never see ourselves as others see us in reality. The only way to do that is to look at a photograph, TV or film picture. The image also appears the same distance behind the mirror as the object is in front of it and therefore looks the same size.

Curved mirrors

The images formed by curved mirrors are different, even though the same rules of reflection still apply. There are, in effect, two types of

curved mirror: concave – where the reflecting surface is inwardly curved; and convex – where the reflecting surface is outwardly curved.

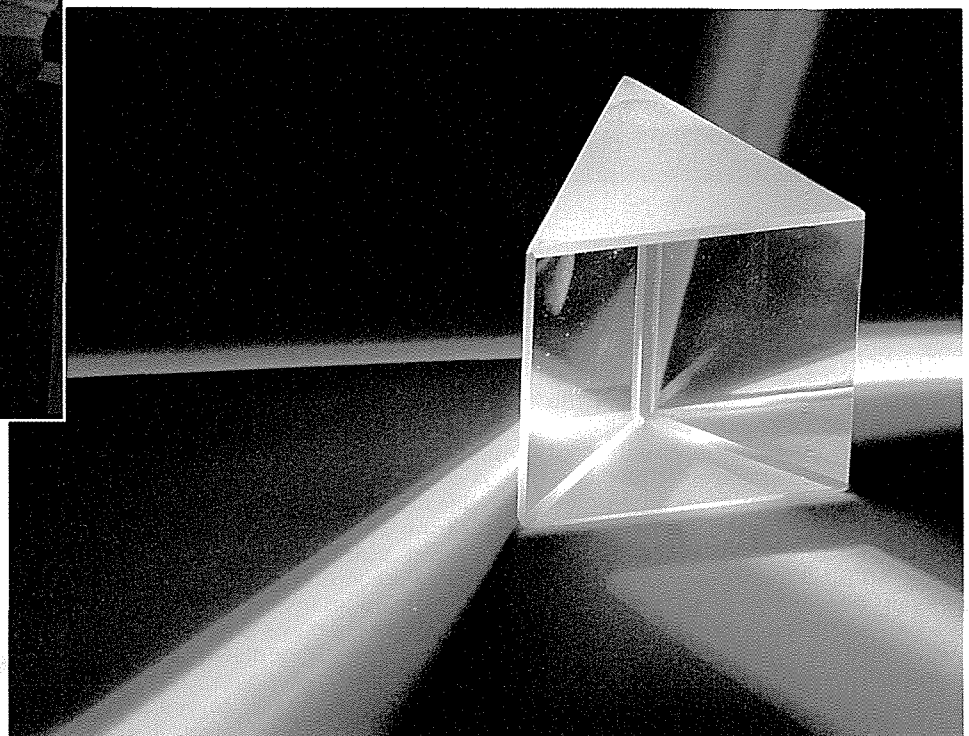
If the mirror is concave, the perceived image can be smaller, larger, or upside down or the right way up. The image you see in a concave magnifying shaving mirror is a larger, virtual image the right way up. The image produced at the focal point of a concave mirror used for astronomy is a real (that is, an image located in front of the mirror) upside down image. Its size depends on the focal length of the mirror.

If the mirror is convex, the image produced is always virtual and



Distorting mirrors use an undulating (wavy) surface, alternately convex and concave, to produce weird, fun-fair effects.

The dispersion of light into its various component colours occurs when it is passed through a prism. Red light is refracted (bent) less than blue light, producing the familiar spectrum.



Spectrum Colour Library

ZEFA



larging lens is the magnifying glass, which forms a larger, virtual image of the object. This happens when the object is placed at a position close to the lens, inside the distance at which it would bring light from a distant object to a focus.

Because lenses are like prisms, light is split into different colours as it passes through them. This effect can cause fuzzy, out of focus falsely coloured images in cameras, tele-

Infra-red equipment can see in the dark – even when there is no light, heat is still given off, so areas of land become visible.

smaller. This fact is very useful for rear-view car mirrors because smaller images allow a wider field of view.

Bending light

The speed of light in a vacuum is approximately 300,000 km/sec. It is slightly less in air, but is significantly less in denser materials such as glass or water. So if a ray of light strikes the boundary between air and glass at an angle, it changes direction and appears to bend. This



Massive satellites would be needed to supply all the world's energy needs from space. They would weigh 50,000 tonnes and have a solar collector area of 50 sq km. They would beam 5,000 megawatts of energy back to a ground receptor (above).

scopes or microscopes. To get round this, lenses with differing powers of dispersion are combined to bring the colours back together at the same point. The dispersion in one lens is corrected by the dispersion in the other. In a two piece achromatic (colour free) lens, crown and flint glass are most likely to be used.

phenomenon is called refraction.

When light passes through a flat sheet of glass it is refracted at the two air/glass boundaries by equal and opposite amounts. So it emerges parallel to the direction it entered. But when the sides of the glass sheet are not parallel, the effect is to change the direction of the light when it leaves the glass. So the path of light through a prism appears to bend at the surfaces.

Light of different wavelengths is refracted by differing amounts as it passes through a prism. This explains why a spectrum is produced when sunlight (made up of all the colours of the visible spectrum) is passed through a prism. The white light is split into its components:

red, orange, yellow, green, blue, indigo and violet.

Refraction is exploited in lenses of various types. Again there are essentially two types of lens: converging and diverging lenses. In a converging lens the middle is thicker than the edges and in a diverging lens the edges are thicker than the middle.

A converging lens works in a way similar to two prisms placed one on top of the other, flat sides together. The light converges towards the centre of the lens and on leaving the lens can form an image. A diverging lens is like two prisms stacked point to point and the light diverges away from the centre.

Lenses can be used to magnify objects. The simplest form of en-

Just amazing!

LONG TIME NO SEE

THE WORLD'S LARGEST DISH RADIO TELESCOPE AT ARECIBO IN PUERTO RICO PICKS UP SIGNALS FROM 15,000 MILLION LIGHT YEARS AWAY. ITS DIAMETER OF 304.8 METRES WOULD COVER 30 FOOTBALL PITCHES.

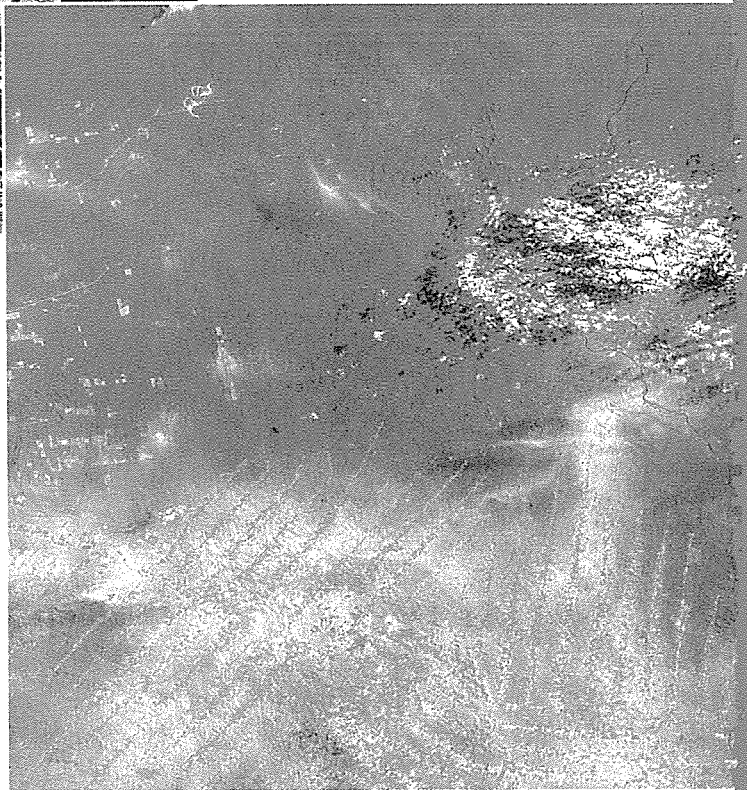




- CROP ROTATION
- ASH FERTILIZER
- SOIL EROSION

FARMING THE JUNGLE

Bananas are just one of the crops produced from cultivated jungle areas. They are picked green and ripen in transit. Over one million tonnes of bananas are imported into Europe every year.



THE US FAST-FOOD INDUSTRY is thought to have been responsible for the destruction of more than a quarter of Central American rain forest: it takes five square metres of rain forest to raise enough beef to make just one American hamburger.

Although about one-third of Costa Rica has been converted to pastureland, most of the beef is exported to the USA. The average Costa Rican eats less beef than the average American pet cat.

A more traditional method of farming in the jungle is 'slash-and-burn' cultivation or shifting agriculture. An area of forest is cleared, usually by slashing through the undergrowth and burning the trees. The ash from the burnt vegetation acts as a fertilizer and crops can be grown for two or three years.

● Regeneration

Soil rapidly becomes worn out by this sort of farming and the people move on and clear a fresh area. The jungle takes 15 or more years to grow back, after which the land can be used again.

So long as the number of people farming this way remains relatively small, this method of agriculture works reasonably well. But if there are too many people in an area, old sites have to be reworked before the soil has had time to recover.

Overworking occurs particularly when highways are built through

A false-colour satellite picture of western Brazil shows vast areas of jungle (blue/white) that have been cleared by 'slash and burn' farmers. The red areas show healthy vegetation.

the forests and settlers move in to colonize the land. In one agricultural colonization experiment at Iata in the Amazon forest, the cleared fields became virtual rock pavements after less than five years.

● Forest farmers

The Lancandon Maya of southern Mexico are expert farmers. They use the techniques of their ancestors to cultivate their forest plots in ways that mimic the plants in the natural forest.

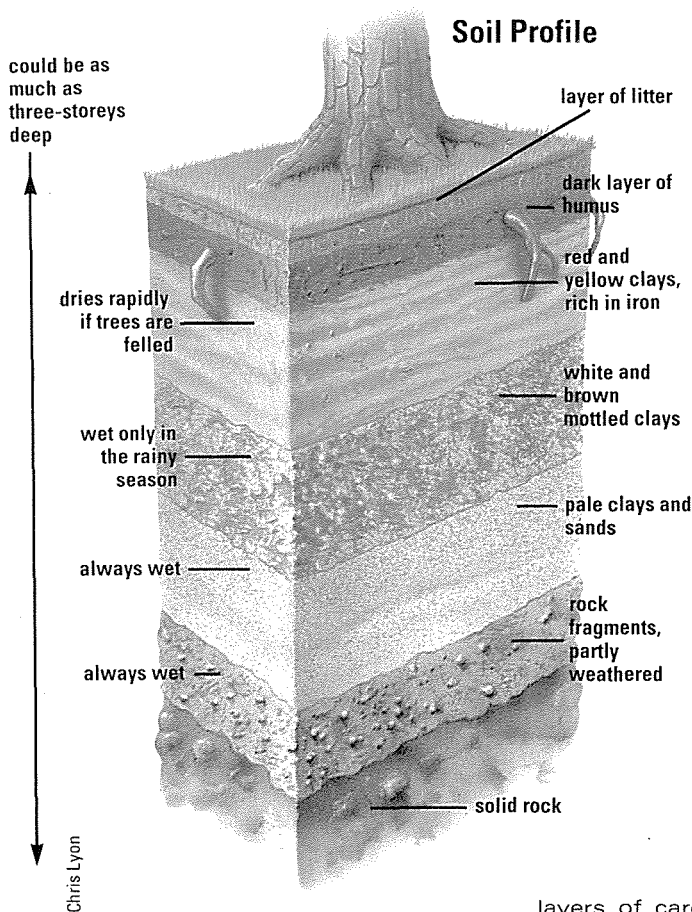
They choose areas of ramon and ceiba trees that grow on rich, well-drained soils and burn the area to create a nutrient-rich ash. To prevent soil erosion, the Lancandon plant fast-growing trees such as banana and papaya to provide shade, and root crops such as taro to anchor the soil. A few weeks later, they plant their staple crop – maize – along with as many as 80 other fruits and vegetables.

Planting times are decided by watching certain 'indicator' plants in the forest. This way they take account of annual variations in rainfall and temperature.

The crops are not planted in tidy rows. Instead, they are arranged in

Ash deposits from the burning of felled trees helps to replenish the soil with essential nutrients. Maize (right) grows well in the cleared areas – but only for a few seasons.





Soil Profile

Deforestation allows the top two layers of soil – the litter layer and the dark humus – to be washed away. The exposed clay then hardens in the Sun.

Scrawny cattle are left to feed on the thin scrub that grows after a forest area has been cleared.

vated peanuts to produce a strain that is resistant to a disease called leaf spot. It is estimated this improvement will save \$500 million a year.

In rain forests, most of the nutrients are 'locked up' in the plants and trees, so the soil is generally poor. If the forest is removed, the frequent heavy rains wash the few nutrients out of the soil. This 'washing out' is called leaching. Fertilizers are very effective where there is sufficient crop plant cover. Even so, the uptake of nutrients is



Hutchison Library

LOOK OUT – NUTS!

Brazil nuts grow on trees in the Amazon rain forests. About 20–30 nuts grow inside large coconut-like pods at the top of trees 30 metres tall. Each pod weighs up to 3 kg and there can be hundreds of pods on one tree.

Some are grown in plantations but they do not produce sufficient profit in one lifetime, so most are gathered from wild trees in the forest.

The pods are harvested when the wind shakes them loose and they drop to the ground. The falling pods can kill, so collectors carry wooden shields for protection. The pods are gathered in baskets and taken to a forest camp where they are cut open with a long knife called a *terçado*. Downriver, the nuts are shelled ready for export. Spoiled kernels and shells are used as fuel to power the shelling plant.



L.C. Marigo/Bruce Coleman Ltd

layers of carefully mixed combinations. This makes the best use of available nutrients in the soil and limits the spread of pests and diseases. There are no spaces between the crops and no land is wasted.

Fallow land

After three to seven years, when the weeds become too difficult to manage, the Lacandon leave the plot to 'rest' for five to 20 years. In the fallow plot, they plant trees such as rubber, citrus and cocoa and harvest from these and other wild plants. The fallow areas attract wild animals, which are hunted to provide valuable protein-rich meals.

Unfortunately, only 20 per cent of the Lacandon still practise their traditional agriculture. The rest have been herded into government-controlled villages so that the forests can be colonized by settlers and cattle ranchers.

New food crops

Many of our foods including bananas, cocoa, coconuts, coffee, aubergines, lemons, oranges, papayas, peanuts, pineapples and tea originally came from the tropical rain forests.

Rain forests are still the potential source of many new crops. Generations of Indians in Paraguay have used the leaves of the stevia plant as a sweetener. Now Japanese chemists have analysed these and found that they are virtually calorie-free, harmless to humans and 300 times sweeter than sugar.

Breeders have crossed wild peanuts from Amazonia with culti-

very slow. Some nutrients pass right through the soil as soon as they are dissolved by rain; others form insoluble compounds. When the jungle soil is cleared of trees, it is exposed to the Sun and oxygen and can turn into a hard, brick-like clay called laterite which, though useful for building, will not support plant life.

The international trade in just nine rainforest spices that are now commonplace in most kitchens – pepper, ginger, cloves, cinnamon, cassia, mace, nutmeg, allspice and cardamom – is worth well over \$500 million. So rain-forest crops are extremely important to many Third World countries.

Just amazing!

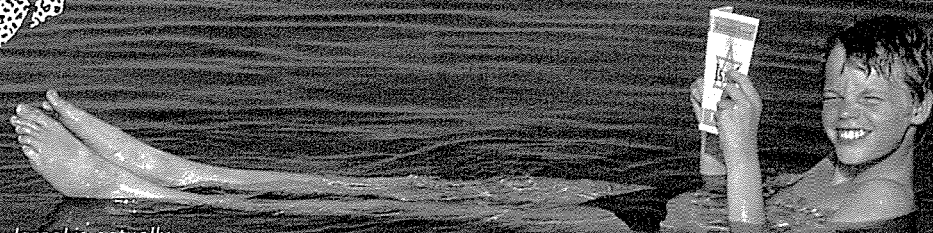
HOME ON THE RANGE

MORE THAN A QUARTER OF CENTRAL AMERICAN RAIN FOREST WAS TURNED INTO GRASSLAND FOR CATTLE IN 25 YEARS. THIS MAKES AN AMERICAN HAMBURGER 5 CENTS CHEAPER THAN IF USING BEEF RAISED ON THE OPEN PRAIRIES OF THE USA



Paul Raymond

EXPLOITING SALT WATER



The Dead Sea in Israel is actually a salt lake with no outlet to the world's oceans. It is so salty that you can float on it with ease, reading a paper if you wish, but no fish can live in it.

SEA OF MINERALS

SALT LAKES

DESALINATION

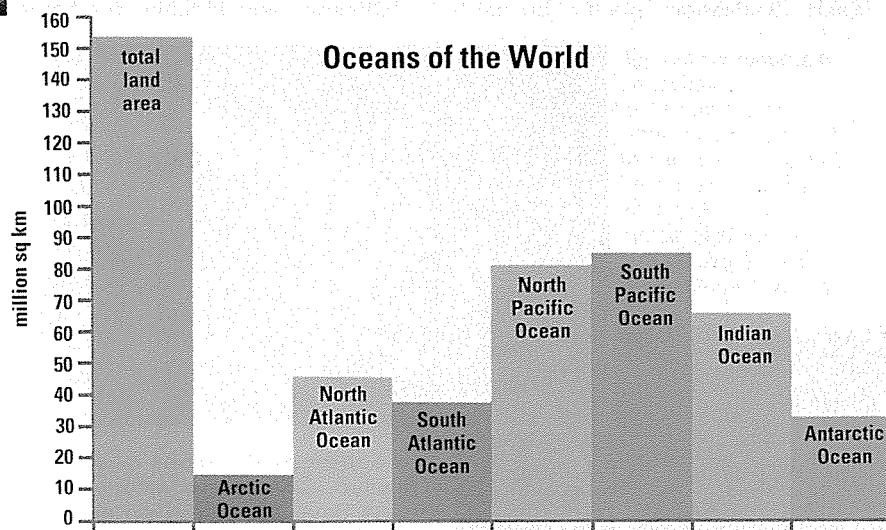
THERE IS NO MORE VITAL resource than water. Yet, although the world has a vast supply, 97 per cent of it is sea water and is too salty for either human or industrial use.

The salts in the ocean are the result of over 2,000 million years of disintegration of volcanic rock from the Earth's surface. Rivers and rainwater constantly wash salty minerals from the land to the sea. Yet the sea does not become saltier and saltier. It has a remarkable self-regulating mechanism (involving the melting of the polar ice caps and evaporation) that has maintained its present composition for millions of years.

Little oceans

When changes in the drainage pattern and climate cut off lakes from the sea, they soon become salt lakes. Great Salt Lake in Utah, USA, is one example. Situated over 1,400 m above sea level, it never was part of the ocean. Isolated from the self-regulating mechanism, salts are filtered out of the surrounding mountains; evaporation prevents the lake from overflowing. Over a period of 100,000 years parts of it have become eight times as salty as the ocean.

Similarly, most of the world's other salt lakes, such as the Dead Sea, Caspian Sea and Aral Sea, have acquired their salt in this fashion, independently of the ocean. They represent oceans in miniature.



Water suitable for drinking should not contain more than 500 ppm (parts per million) of salt. Sea water typically contains 35,000 ppm of salt. So, where fresh water supplies are insufficient, the only alternative to transporting fresh water by pipeline or tanker is desalination. This is the process of converting sea water to water suitable for domestic or industrial use.

Flash distillation

There are various methods of desalination, but the most effective is known as flash distillation. This involves heating the sea water to a temperature of about 90°C and then injecting steam to raise it further to about 120°C. The hot water is then

The oceans of the world together account for two thirds of its surface area. The boundary between the North and South Atlantic and Pacific Oceans is the equator.

passed to a low-pressure chamber where it instantly boils in a process called 'flashing'. The resulting steam is then cooled and condenses into pure water.

Large flash distillation plants are usually situated in particularly dry areas near the sea. One near Tijuana, on the Mexican coast, produces 27 million litres of fresh water a day.

The major drawback with this type of desalination is cost. One



A desalination plant at Dubai, United Arab Emirates. Making fresh water from the sea is an extremely costly process, only carried out by rich nations.

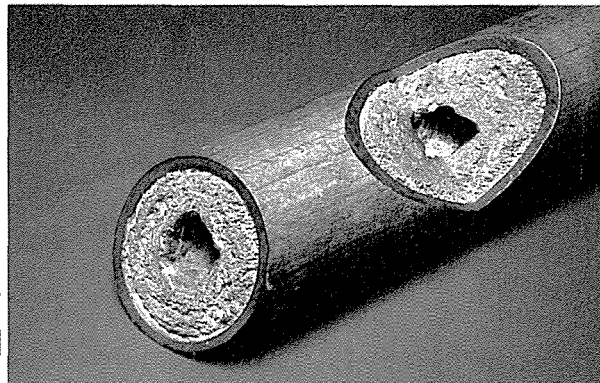
method of reducing the cost, favoured by Israel, is to employ the waste heat from a nuclear power plant to raise the sea water to the necessary temperature for flashing. Even so, flash distillation plants are only affordable by oil-rich nations such as Saudi Arabia and Libya and advanced ones, such as the USA. The need for fresh water, however, is so great that there are over 20 flash distillation plants currently

operating and it is predicted that by the end of the century there will be at least 70.

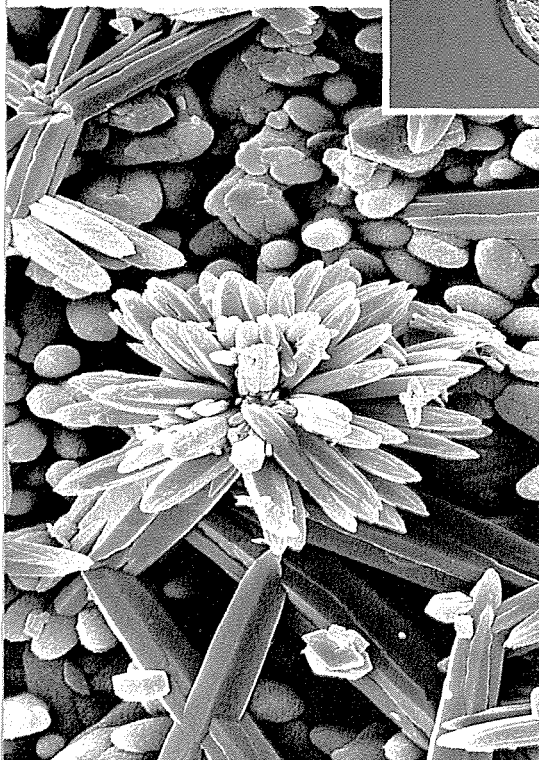
The other main desalination process is electrodialysis. This involves using an electric current to separate fresh water from a salt solution. Electrodialysis plants with outputs of up to 2.25 million litres per day are commonly used to treat brackish water in the USA.

Cheaper and simpler but limited

A photograph through an electron microscope of 'fur' from a domestic kettle. This is formed from salt crystals found in hard water and can be dangerous in factory pipes (right), boilers and water containers.



Permutit Co Ltd



Dr Jeremy Burgess/SPL

to sub-tropical regions is solar distillation. Several successful installations have been built on especially dry Greek islands, notably on Simi, near Rhodes.

● Salt water crops

Over the last 20 years, agricultural scientists have done a great deal of work on the problems of irrigating with salt water. It has been found that not only can salt water be used successfully on sandy or gravelly soils but that some crops will happily accept a salt water diet. These include a dune grass, useful as animal fodder, a desert cactus, that can be used by the chemical and textile industries, and sugar beet.

Unusual, but not unique, is a rush (*Juncus maritimus*) that actually desalinates the soil in which it grows. When harvested, it produces pulp for the manufacture of high-grade paper.

THE NEED FOR SALT



There is no doubt among dietitians: too much salt is a bad thing. It is believed that the taste for salt, in the form of normal table salt (sodium chloride), sea salt (with additional iodine) or a salt substitute (potassium chloride) is a 'learned response' - you learn to like it because it has always been added to your food, either in the cooking or at the table - often both. Excess salt in your diet can lead to an increase in blood pressure and can strain the kidney.

The average person consumes about 10g of salt per day yet your body needs no more than about 1g of salt a day. However, a lack of salt, called hyponatremia, can have dramatic effects. The first signs are cramp (the involuntary and painful bunching of muscles, normally in the calf), muscle spasms (sharp pain associated with slow movement) and a slight rise in the heart rate. Severe salt depletion - not through sweat - will lead to a large rise in blood pressure, coma and death.

Just amazing

NOT A DROP TO DRINK

IF ALL THE SEAS DRIED UP THERE WOULD BE ENOUGH SALT LEFT TO BUILD A WALL 1 KM HIGH AND 1 1/2 KM THICK AROUND THE EQUATOR.



WATER CYCLE

- ICE CRYSTALS
- FOSSIL WATER
- THE WATER TABLE

WATER IS BY FAR EARTH'S most abundant liquid, covering about three quarters of the Earth's surface.

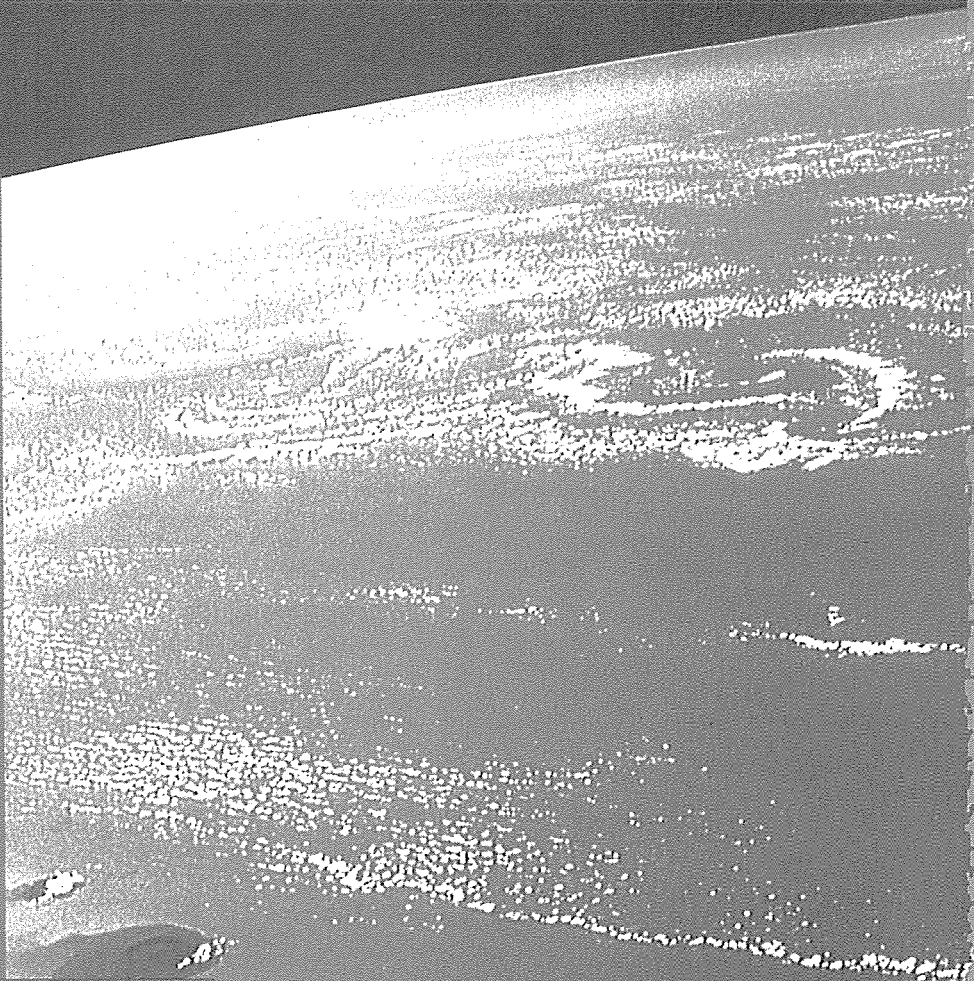
About 97 per cent of the water is salt water in the oceans; the remaining three per cent is fresh water.

The amount of fresh water has been calculated to be more than 37 million cubic km — enough to fill the Mediterranean over ten times. Most of this fresh water is continually circulating in what is known as the water cycle.

Water from the sea is taken up into the clouds. It falls from the clouds on to the land. Some of the water flows down into the sea again; some is taken up into the air directly; some drains into stores of water under the ground.

Power of the sun

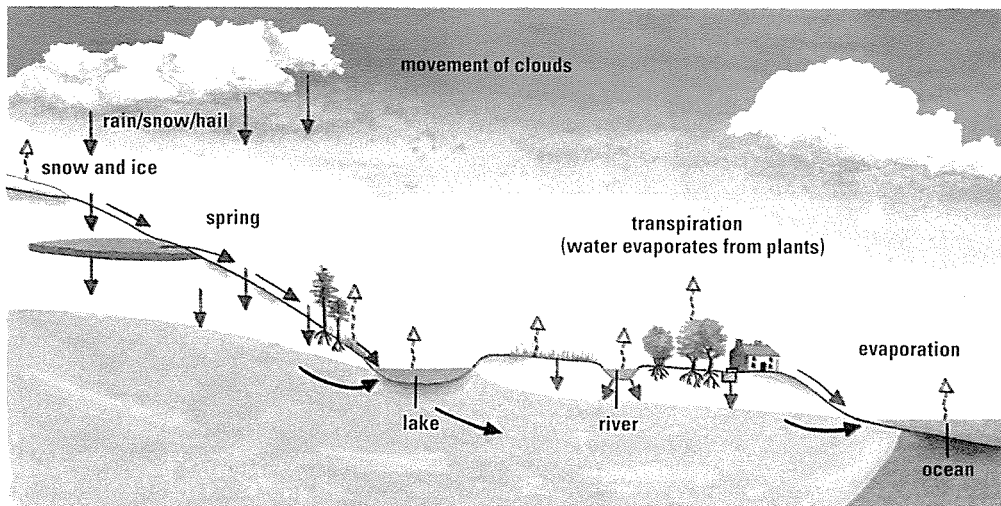
The driving force behind the water cycle is the Sun. The heat of the Sun evaporates water from the oceans and the land. (Evaporation is the changing of liquid to vapour). Water evaporates into the air and



Rainfall is measured as the depth of water that would have covered the ground if no water ran off into streams or drained into the soil

© Tony Stone Photo Library / London NASA SPL

Clouds, made up of masses of tiny water droplets, above the Atlantic Ocean and the Cape Verde Islands off the west coast of Africa.



The water cycle is the process whereby water evaporates into the air from the sea, rivers, lakes and the leaves of plants, and returns to the land (and sea) in the form of rain, snow or hail. Some of the rain drains underground and remains there, or seeps back into the oceans.

forms clouds, leaving the solids – including the salt – dissolved in the water behind.

The clouds are blown by the wind from above the sea to above the land. In the clouds, in the cold of the upper air, vapour changes into droplets of water – each droplet forming around a tiny fragment of dust.

Droplets join together until they are too large and heavy to float on the air currents and they fall to the ground as rain. Sometimes droplets that are not yet heavy enough to fall are carried higher, where the air is even colder. Here, tiny frozen droplets – ice crystals – are formed, when vapour freezes around dust particles in the air – snowflakes are

comes so heavy it plummets to the ground, falling so fast it does not have time to thaw.

Some of the water that sinks into the ground is absorbed by plants, and then transpired into the air. Transpiration means the evaporation of water through pores on the undersides of leaves called stomata. These open during the day and close at night.

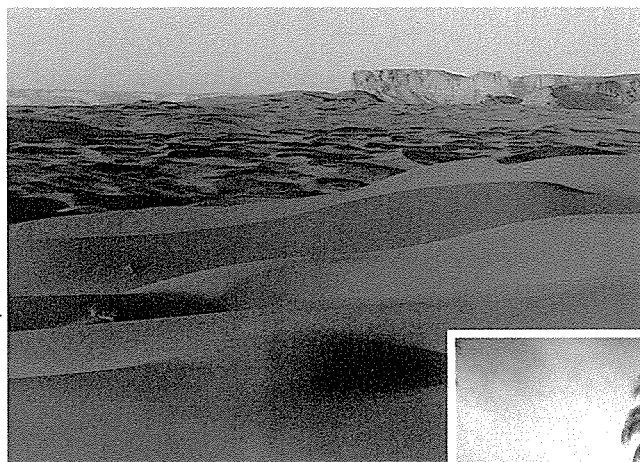
● Transpiration

The rate of loss of water from the leaves depends on the intensity of light, the humidity (the amount of moisture in the air), the temperature and the strength of the wind.

In a desert, the rate of water loss

from leaves is high because of the hot sunlight and the dry air. (Leaves have adapted by developing thick waxy surfaces that prevent as much water as possible escaping from the plant).

In contrast, the high rainfall and still air of the tropical rainforests ensure there is so much water

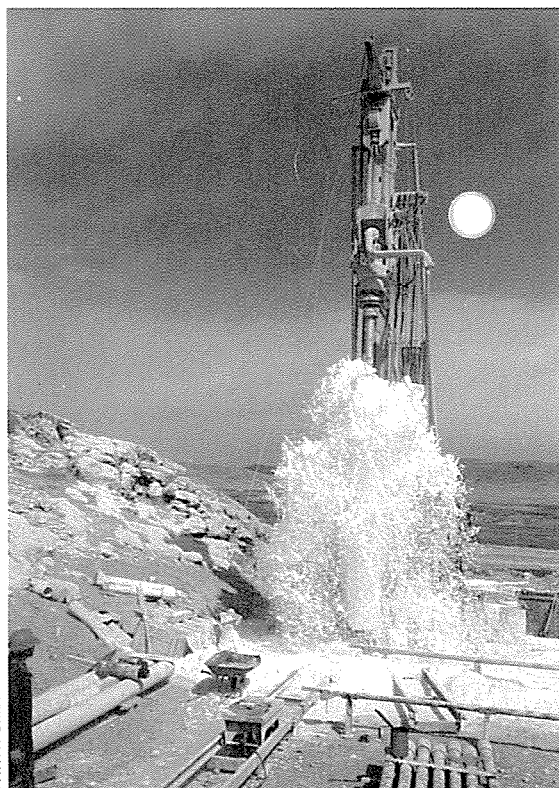
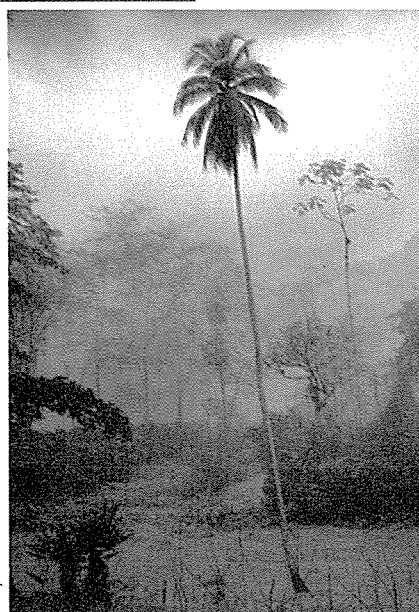


Water is scarce in the desert because rainfall is low – less than 25 cm a year – and the rate of evaporation very high in the dry, hot climate. Day temperatures can rise to between 30 and 40°C.

Tropical rainforests are hot and humid, having at least 150 cm of rain each year. Evaporation is low because of the amount of water vapour already in the air.

ice crystals joined together. Often, however, ice crystals melt on the way down and reach the ground as rain.

Hail is frozen raindrops. A frozen droplet is carried up again and again to the level of the atmosphere where water freezes. On each trip upward another layer of ice freezes on to the droplet, the droplet falls and then air currents buoy it up again. Eventually, the hailstone be-



A drilling rig, sinking an artesian well in Iran. The water gushes out under natural pressure, without being pumped.

vapour in the atmosphere around a transpiring leaf that very little water escapes from the stomata.

Water that is not absorbed by plants passes underground along cracks and crevices in rocks until it reaches a layer of rock through which it cannot pass. The water flows along the upper surface of this non-porous layer until it finds

Droplets freeze on to the body of an aeroplane flying through clouds so high that the temperature is well below 0°C. The wings must be de-iced before the aeroplane flies again.

Some aquifers have been in existence for a very long time. These stores of 'fossil water' are preserved between layers of impermeable rock. For example, below the Sahara desert are aquifers that originated in the last Ice Age and are up to 35,000 years old. Because rainfall is so low, in many areas this is the only source of water. Aquifers are slowly being drained, because the fossil water that is pumped to



A hailstone is formed by layers of ice freezing on to a frozen raindrop. A cross-section reveals a structure like an onion. Stones usually fall in a short, heavy shower as part of a thunderstorm.

an outlet on to the surface of the land, where it flows out as a stream. Several streams join together to form a river which flows to the sea, continuing the cycle.

Water that does not escape on to the surface accumulates underground, where it is known as groundwater. The pores of the rock levels above the non-porous layer become filled with water. The top surface of this saturated layer is the water table. As the water at the base of the porous rock runs out, the water table lowers. If there is a drought, the water level also falls, because the amount of water percolating down from the surface has lessened.

Underground

A store of water below the surface is called an aquifer. Boreholes are drilled down to aquifers and the water brought to the surface and used for watering crops on desert and semi-desert land. Sometimes the water wells up under its own pressure, but as the level of water in the aquifer falls, the water has to be pumped up.



St Mark's Square has been under water in floods. Venice has suffered, partly because of land subsidence caused by pumping up groundwater.

the surface cannot be replaced.

The 'centre-pivot' method of mining underground water is commonly used in southern and western regions of the USA, where there is not enough rain to grow crops. A borehole is sunk into the aquifer; water is pumped up and sprayed over the crops using a revolving boom hundreds of metres long.

However, this method uses up a great deal of water. Much more water is being taken out of aquifers than can pass in. In parts of Texas, the water table fell by more than 100 metres in the 1970s and 1980s. Water that has fallen as rain, draining through the soil and porous rock layers, only raises the level of the water table between one and 12 mm a year.

Fighting the sea

In an aquifer near the sea, below the top layer of fresh water is salt water. This has seeped in from stores of sea water in layers of porous rock beneath the sea. Re-

Just amazing!

KILLER STONES

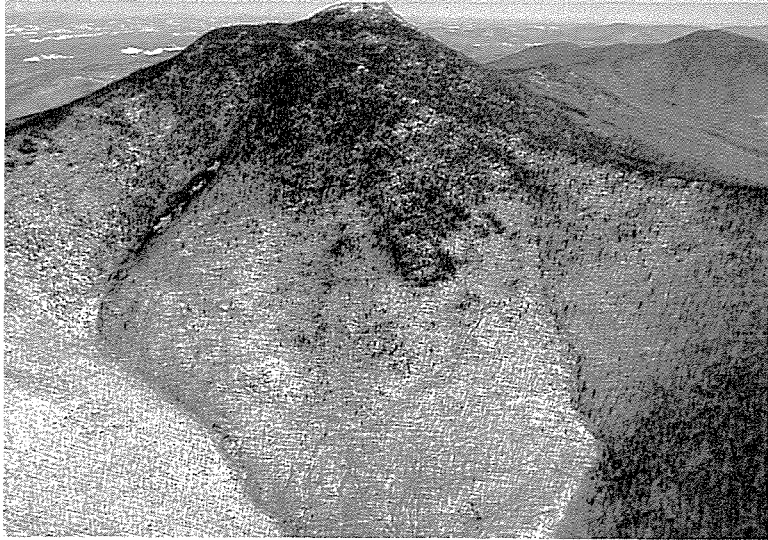
GIANT HAILSTONES KILLED 92 PEOPLE IN BANGLADESH IN 1986. THE HAILSTONES, THE HEAVIEST ON RECORD, WEIGHED 1.02 KG EACH - OVER TWICE THE WEIGHT OF A FOOTBALL.



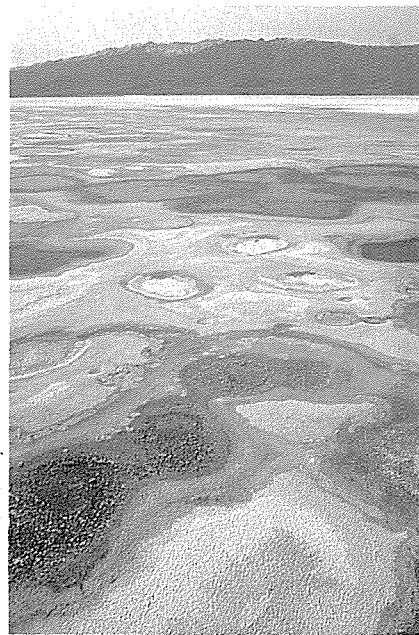
PROFILE

THE WORLD'S LONGEST RIVERS

River	Outlet	Length in kilometres	Average discharge of river into outlet in cubic metres a second
Nile	Mediterranean Sea	6,650	3,000
Amazon	South Atlantic Ocean	6,440	180,000
Chang Jiang	East China Sea	6,300	34,000
Mississippi	Gulf of Mexico	6,020	18,000
Yenisey	Kara Sea	5,540	19,000
Huang He	Gulf of Chihli	5,460	(no figure available)
Ob	Gulf of Ob	5,410	15,000
Parana	Rio de la Plata	4,880	22,000
Zaire	South Atlantic Ocean	4,670	41,000
Amur	Sea of Okhotsk	4,440	12,000



Red spruce in Vermont, USA killed by the increase in soil acidity due to acid rain. Smoke, fumes and exhaust gases have polluted the rain so that it is sometimes as acid as vinegar.



Salt pan on the floor of Death Valley, California. Rivers washed salts into a shallow lake on the valley floor. The salt was left behind when the lake evaporated.

Townsend Dickinson/SPL

move the fresh water, and the salt water will rise to replace it.

This happened in the Tel Aviv area of Israel when intensive farming and new factories depleted local aquifers' supplies of fresh water. The water in them became more and more salty.

Israel solved the problem by bringing in fresh water from wetter,

Marghera on the mainland opposite the centre of the city. As the land subsided, the number of floods, and their severity, increased. The rate of use of groundwater is now strictly controlled. It is planned that, once canals have been built to bring water down from hills on the mainland, no water will be used from the aquifers.

Irrigation networks are being improved in East Java, Indonesia, in order to increase crop yields, especially of rice. Instruction in the operation and maintenance of an irrigation scheme is essential.



Mott MacDonald

Every year, the world's rivers carry 2,000 million tonnes of mineral salts down to the sea. Where artificial irrigation channels have been dug, mineral salts are held on the land instead – they are not washed downstream and away. As plants transpire and water evaporates into the atmosphere, salts in the water are left behind. They accumulate in the soil, until the soil becomes barren.

When it rains, some of these salts are washed through the soil and into the groundwater. The groundwater eventually becomes so salty that the soil becomes infertile and no crops can be grown.

northern Israel along specially dug canals. It is poured into a line of wells along the coast, and down boreholes directly into the aquifers to raise the water table.

A similar problem is occurring in Spain where fresh water is being pumped up from aquifers to water tomatoes. In places, the water has become too salty to grow the tomatoes.

Another problem is land subsidence. As water is pumped out, the land settles, creating depressions. For example, during California's six-year drought which ended in 1992, farmers used so much ground water that the water table fell, causing land in parts of the Central Valley to subside by as much as nine metres.

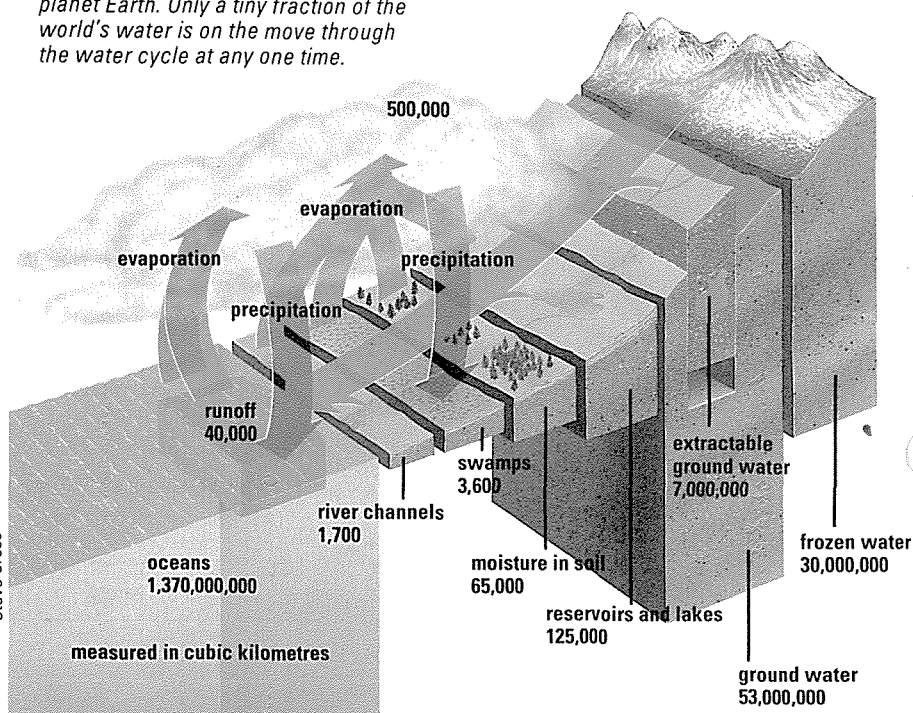
● Venice is sinking

Venice (built on 118 islands just off the coast of Italy) is sinking at the rate of 30 cm a century. A major reason for this is that aquifers are being emptied by electric pumping to supply factories at the port of

Steve Cross

Each section represents a different form in which water is stored on the planet Earth. Only a tiny fraction of the world's water is on the move through the water cycle at any one time.

The World's Water



SOUND VIBRATION

- SOUND ENERGY
- MUSICAL NOTES
- ULTRASOUND

SOUND IS A FORM OF ENERGY.

It is vital to our understanding of the world because we communicate so much through sound, and the world is full of sound — doorbells ringing, records playing, and people talking.

Sound energy is produced when an object vibrates. The vibration sets the surrounding air in motion and the air carries the vibration as waves — it is these sound waves that we pick up with our ears and interpret in our brains; that is when we hear the waves as sound.

● Silent vacuum

Think of air as a liquid and the sound waves as ripples and you will understand why there can be no sound inside a vacuum — because there is no air.

Some vibrations are over very quickly, while others last much longer. When you clap your hands the vibration doesn't last very long — it is little more than a shock wave in

the air. But you can make a sound which lasts much longer. Put a ruler on the edge of a table, hold down one end, and ping the other end. You can see and hear the ruler vibrating for a few seconds. When you speak, it is the vibration of your vocal cords that makes the sound. If you put your finger on the 'Adam's apple' of your throat as you speak you can feel your vocal chords vibrating with the sound.

The sound of the ruler is a sort of

rattling hum. But a tuning fork makes a much purer ringing tone when struck. This is because the sound waves from the tuning fork are more regular and smooth. The more even and regular the vibration of the sound, the nearer it gets to being a musical note.

● Sine waves

Sound waves produced by the tuning fork are much more regular than the sound waves produced by a door shutting, for example. The regular wave made by a tuning fork is known as a sine wave.

Not many sounds occur as pure sine waves — only pure musical notes. Most sound waves are much more complex.

● Pitch and volume

The more frequently the air is compressed, the higher the pitch of the sound, and the more air particles are compressed, the louder the volume.

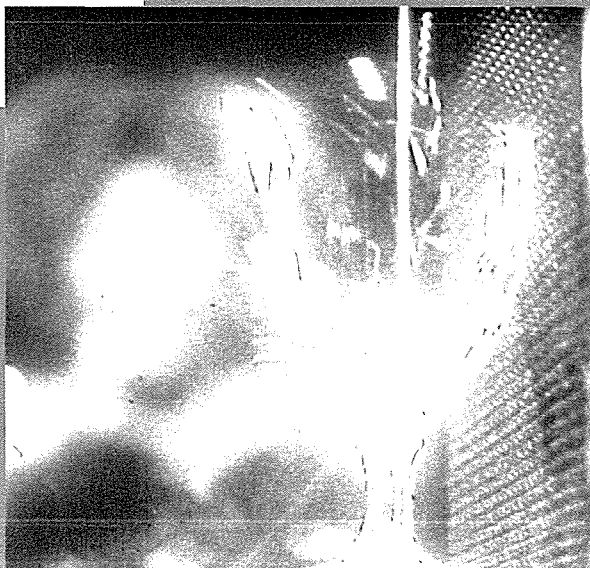
Sound travels at about 340m/sec at sea level, but light travels almost a million times faster — which is why you see lightning before you hear thunder during a storm.



Tony Stone Photo Library, London



Shattering glass with her voice, jazz singer Ella Fitzgerald can hit such pure notes that they act like a beam of ultrasound. The molecular structure of the glass vibrates to such an extent that it breaks up and the glass shatters. The effect was used in an advert for cassette tapes, where the manufacturer claimed that their reproduction was so pure that even a recording of Ella shattered the glass.



Memek Products

Vocal cords are two strong bands of tissue inside the larynx which vibrate as air from the lungs passes through. The effect is similar to the way the reed produces the sound in woodwind instruments.

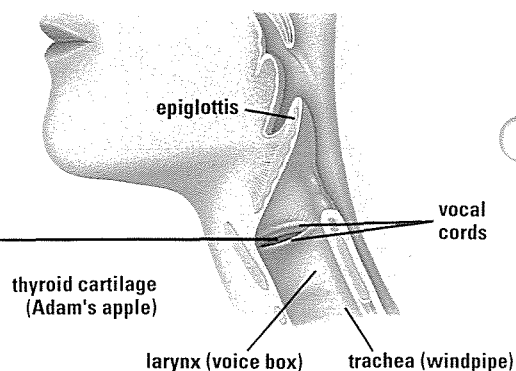
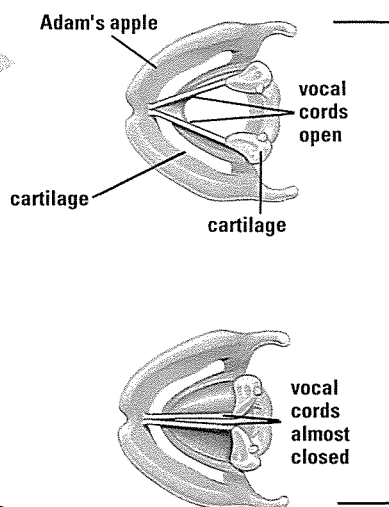
Some aircraft, such as Concorde, travel faster than the speed of sound. As it approaches the speed of sound, it begins to catch up with its own sound waves. As it overtakes them, it breaks the sound barrier, causing a shock wave – the sonic boom.

The Doppler effect

When a police car passes you with its siren going, the tone sounds higher as the car approaches than it does as the car speeds away. This is known as the Doppler effect. The sound waves in front of the car get squashed together as it approaches, so the pitch of the note is higher. When it moves away, the waves are stretched and the pitch is heard as lowering.

Like all forms of energy, sound can be put to use. Ultrasound is

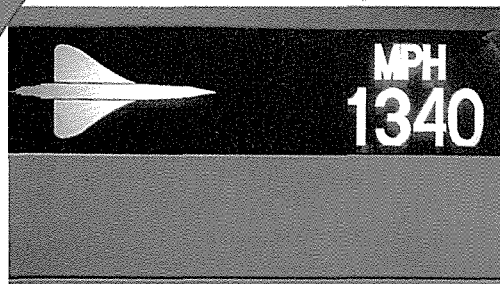
Heavy or rapid breathing



During rapid breathing, the vocal cords are wide open, but when they close up, they produce a higher-pitched note. Normal speech is a mixture of the two.

Making a high-pitched sound

A sonic boom is produced when a supersonic plane such as Concorde flies faster than the speed of sound. The boom comes when the plane 'overtakes' its own sound waves, and is shown in a cockpit display panel in front of the pilot.



DRUMBEATS

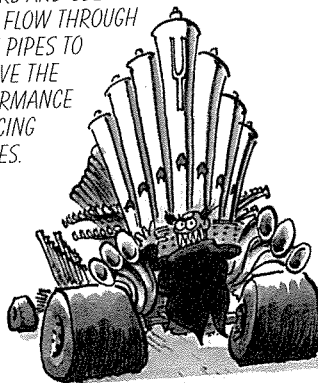
The beat of a drum shows how sound waves are made in the air. When you hit a drum the skin first goes down very quickly. It returns to its original position again but because it is elastic it bounces past the original position and keeps going until once again it reaches the limit of its elasticity. Then down it goes again.

The drumskin keeps going up and down until all the energy of the original strike is used up and it rests at its original position. All the time it has been vibrating up and down you have been hearing the beat, which goes on for a few moments after the drum is struck. Every time the skin goes up it compresses – squashes together – the air particles, and in between the waves of compression are waves where the air particles are 'stretched out'. It is these compressions and stretches that form the sound waves you hear.

Just amazing!

FINELY TUNED

YAMAHA – THE MOTORBIKE MANUFACTURERS – ARE ALSO ORGAN BUILDERS AND USE THEIR KNOWLEDGE OF AIR FLOW THROUGH ORGAN PIPES TO IMPROVE THE PERFORMANCE OF RACING ENGINES.



extremely high pitched – much too high for us to hear – and spreads out much less than low-pitched sound. It can be transmitted in a very tight beam, and the echoes which reflect back can be changed into electrical impulses to give a picture of the object that is reflecting the sound. Ultrasound can be used to produce a picture of hidden

objects. For example, ultrasound can locate wrecks on the sea bed and shoals of fish, and doctors use ultrasound to check the developing baby inside a pregnant woman.

Ultrasound beams are also used by physiotherapists in the treatment of damage to muscles and joints. The waves of sound 'massage' the soft tissues, which aids healing.

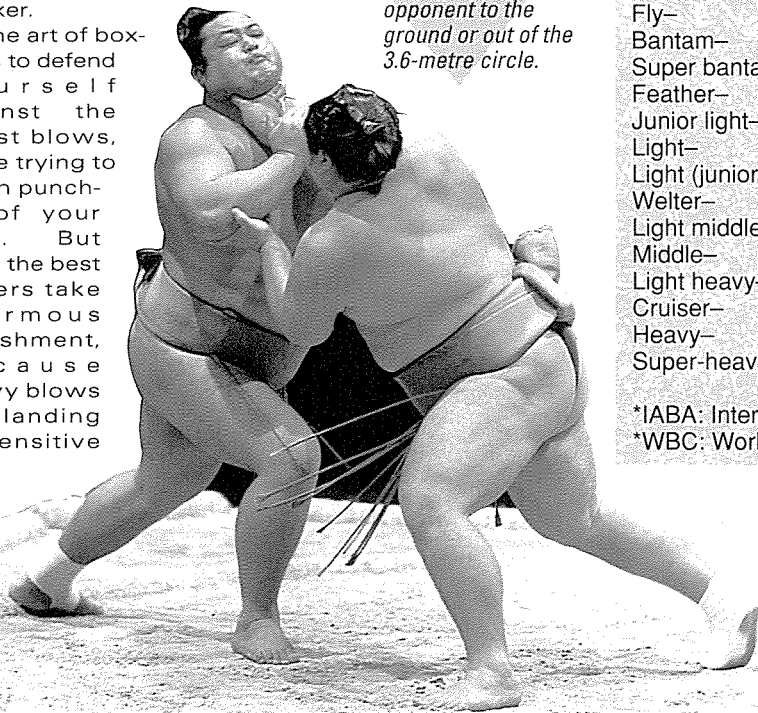
Auto tuners are often used for quick tuning. The guitar is plugged in, and digital LEDs show when each string is at the right pitch. The letters C D E F G A & B represent musical notes, and the numbers above them are the strings of the guitar.



fighters can run grave risks – the more so because a fighter's injuries may only be apparent after the fight. In addition, deciding that a fighter is unfit to continue boxing is left to the discretion of the referee who, being human, may make a mistake and not stop the fight before serious injury has been done to a boxer.

The art of boxing is to defend yourself against the worst blows, while trying to get in punches of your own. But even the best boxers take enormous punishment, because heavy blows are landing on sensitive

Sumo wrestling is the heavily ritualized Japanese national sport. Great reliance is placed on weight, with some champions scaling over 130 kg. The aim is to force an opponent to the ground or out of the 3.6-metre circle.



Vandystadt/Allsport

areas of their bodies throughout the bout. Muhammad Ali, for instance, has calculated that he took 1.5 million blows in his 25 years in the ring.

The worst types of injury, however, are to the head. Brain injuries caused by punches can be of three kinds:

- straightforward concussion, which results from a shock wave through the brain and renders the victim unconscious.

Thai boxing is a fast-moving martial art that grew out of the ancient Siamese military training syllabus. In its modern form, contestants are matched as much by experience as weight. Boxers wear 220 gm gloves and can punch the body or the head. Kicks with the shin and knee are allowed to the legs and body but not to the head. Bouts are over three 2-minute rounds or five 3-minute rounds.

- a torn blood vessel, which quickly leads to unconsciousness
- slow bleeding in the brain with a delayed onset of unconsciousness.

Other major problems that boxers can suffer are having the retina of the eye detached by frequent blows to the head, and damage to the soft tissues of the brain.

Bare-knuckle fighting

This last injury is thought to be one of the main causes of boxers becoming 'punch drunk' – the condition that is shown by the dulled reflexes

PROFILE

BOXING DIVISIONS

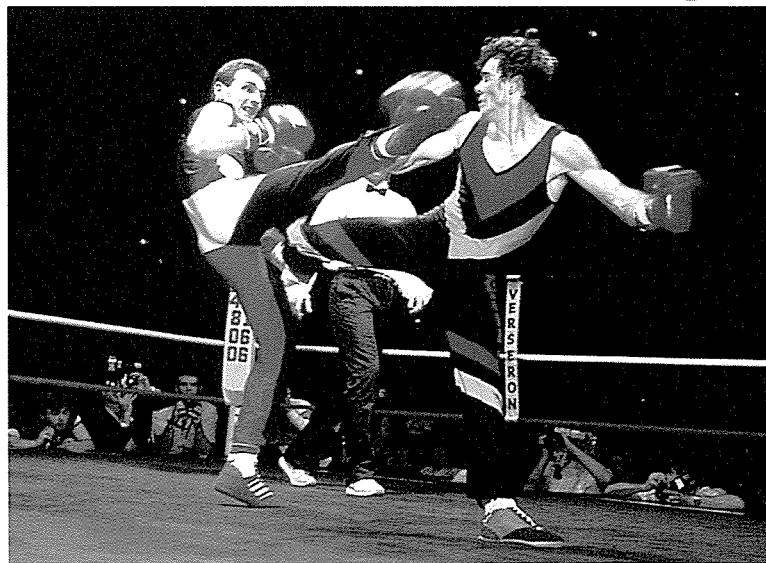
Weight categories	Amateur (IABA*)	Professional (WBC*)
Straw–	—	47.6 kg
Light fly–	48 kg	49 kg
Fly–	51 kg	51 kg
Bantam–	54 kg	53.5 kg
Super bantam–	—	55 kg
Feather–	57 kg	57 kg
Junior light–	—	59 kg
Light–	60 kg	61 kg
Light (junior) welter–	63.5 kg	63.5 kg
Welter–	67 kg	66.5 kg
Light middle–	71 kg	70 kg
Middle–	75 kg	72.5 kg
Light heavy–	81 kg	79 kg
Cruiser–	—	88.45 kg
Heavy–	91 kg	88.45+ kg
Super-heavy–	91+ kg	

*IABA: International Amateur Boxing Association

*WBC: World Boxing Council

and slurred speech of many ex-boxers. It will usually involve memory lapses, blackouts and even premature senility, yet may only show up years after a boxer has retired from the ring.

The problem has led one boxing magazine to argue for a return to bare-knuckle fighting. This was the

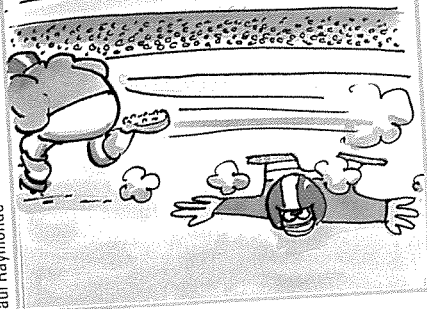


Sipa/Colorsport

Just amazing!

SHORT CAREER

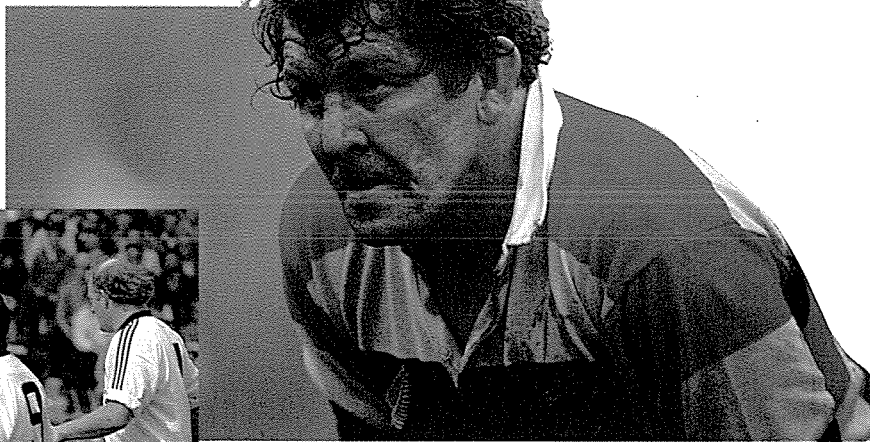
IN 1970 PAT PALINKAS BECAME THE FIRST LADY AMERICAN FOOTBALLER WHEN SHE HELD THE BALL FOR HER PLACE-KICKER HUSBAND. SHE RETIRED IMMEDIATELY AFTER A LINEBACKER FLATTENED HER!



Paul Raymond

shoulder pads, hip pads, thigh pads and knee pads. They may also choose to wear shin pads, a kidney and rib protector, elbow pads, gloves and a gum-shield.

The range of tackles and blocks available to American footballers is



Russell Cheyne/Allsport

Rugby League is essentially a handling game. Although a drop-goal is kicked over the bar it is worth less than a 'try'. Superficial injuries (above) are a common feature.

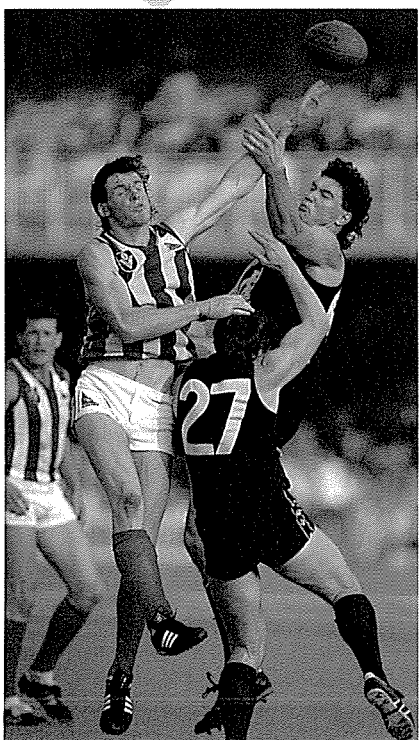
ankles, severe bruising and bone fractures. But, as in rugby, it is not unheard of for players to be paralysed by broken spines, or, very rarely, killed.

The most lethal of all contact sports, however, is undoubtedly boxing. The aim of boxing is to land more and better punches than your opponent. However, in doing so,

Colorsport wider than in rugby. The whole body may be used to block or obstruct an opponent, so weight can be very important. A typical play will see the ball passed back to the quarterback by the centre of the offense, while each of the linemen tries to bludgeon his way past his opposite number. The quarterback will usually try to throw the ball to a wide receiver who will probably have two or more tacklers running at him to bring him down as soon as possible.

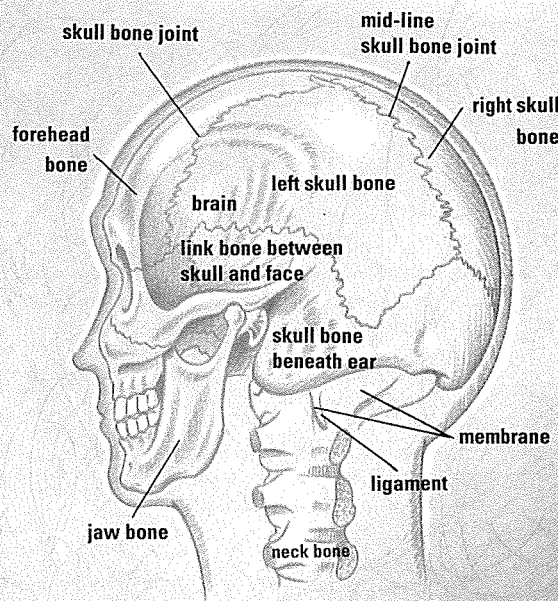
So it is not surprising that there are some serious injuries. The most common are strains of the knees and

Australian Rules Football is a tough game unique to Australia, fought between teams of 18 players over pitches 150 to 200 metres by 120 to 170 metres.



David Cannon/Allsport

THE HIDDEN DANGERS OF HEADING A FOOTBALL



(left), intent on forcing him off line and balance.

Incorrect technique can result in concussion and, rarely, in more serious injury. Whereas the joint between the two halves of the skull – the mid-line skull bone joint (above) – normally knits into a strong spherical shape, it can join imperfectly, leaving a small, and relatively weaker, ridge. In such cases, incorrectly heading a football can move the skull bones fractionally, causing headaches or double vision.

A further problem is the accumulative wear of heading on the muscles of the neck. If over-strained, the small ligaments and membranes in the neck can tear and this may lead to an increasing likelihood of painful arthritis of the neck some 15 or so years later.

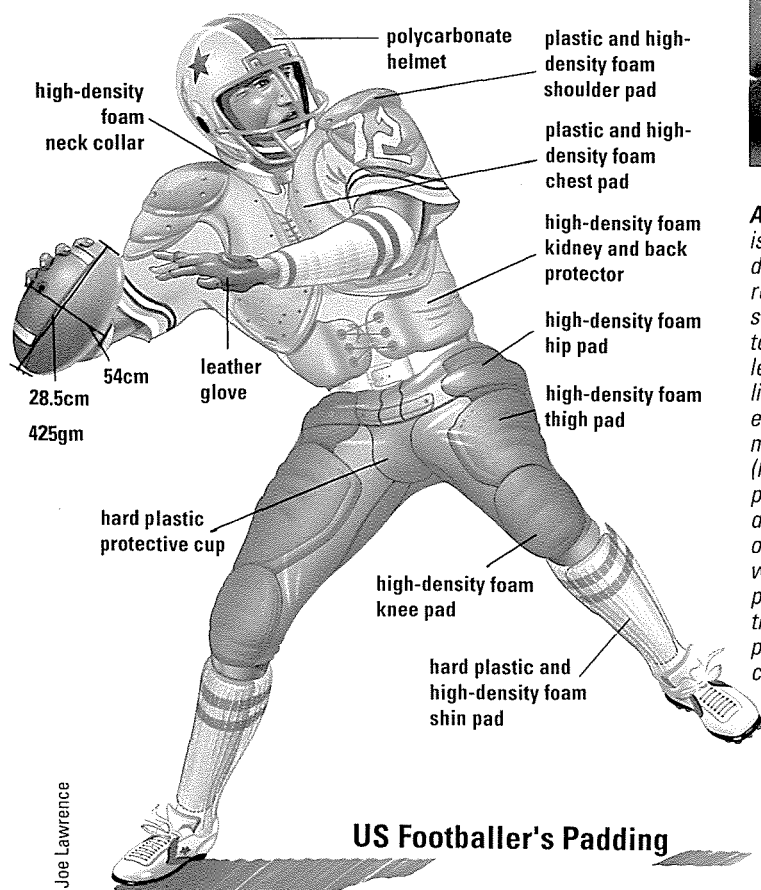
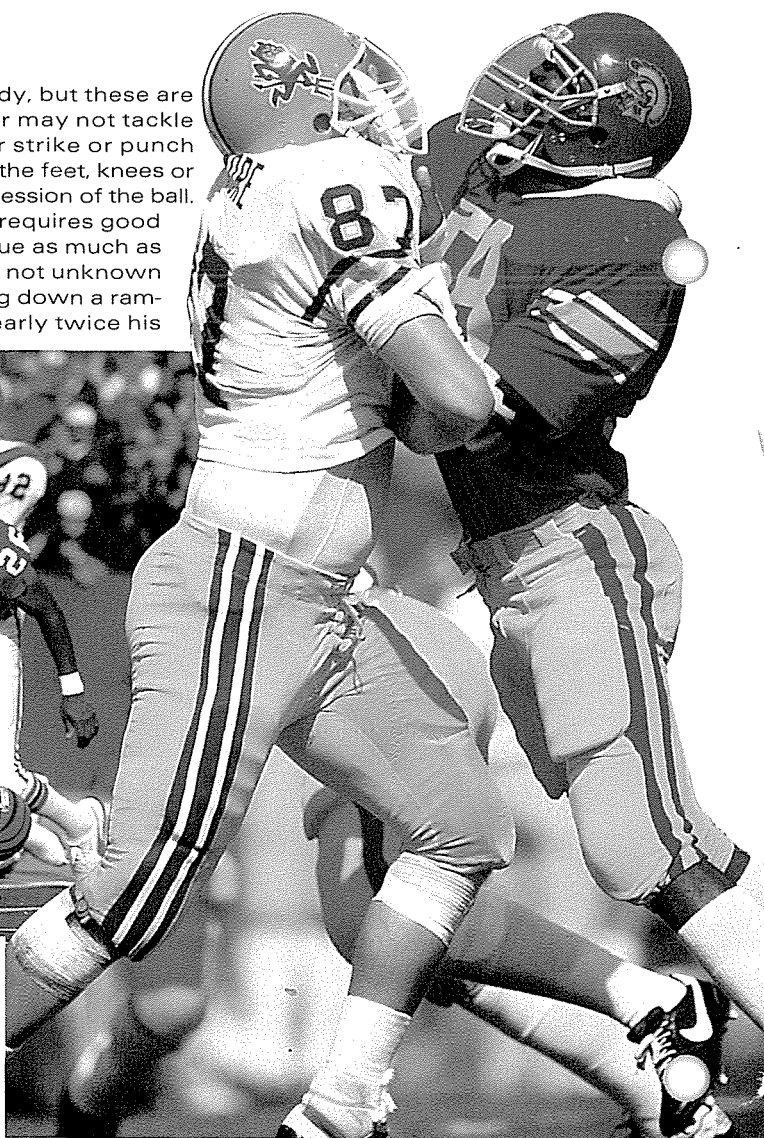
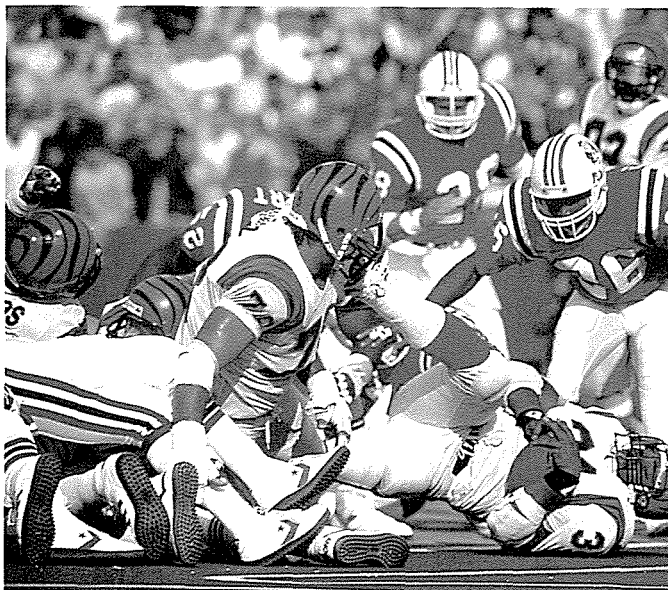
Joe Lawrence

One of the most spectacular and unique techniques in football is the use of the head to play the ball. Typically, the 450 gm plastic-covered ball contacts a player's head at 70 km/h, so correct method is essential, not only to maximize control but to help prevent injury. Players are taught to fix their eyes on the ball, watch it on to the forehead and cushion its force by bracing their neck muscles. In the hurly-burly of a game, however, an attacker often has to contend with one or more defenders

In team sports, size and weight are not always helpful. Ball sports such as rugby also require speed, great agility and stamina. So teams tend to have a blend of large, heavy players and smaller, quicker ones, who fulfil different roles.

The large players either force a way through their opponents' defences, like human battering-rams,

the opponent's body, but these are regulated. A player may not tackle above the neck, or strike or punch deliberately or use the feet, knees or elbows to win possession of the ball. The perfect tackle requires good timing and technique as much as brute strength; it is not unknown for a fly-half to bring down a ram-paging forward nearly twice his



US Footballer's Padding

or present their own defensive line, like a wall. In rugby, these players are called forwards, and the lighter, faster – and usually more skilful – players are known as the backs.

Rugby allows direct tackles on

weight with a well-timed tackle. But in 'rucks' and in the scrum, weight is a great advantage.

The division between forwards and backs is even more starkly illustrated in American football, which

American football is a much modified descendant of rugby. Although the scoring method – a touchdown (above left) over the goal-line – is similar, extensive body armour is worn (left). This is to prevent injury during tackles and off-ball blocking, where offensive players 'block' their opponents to protect the ball-carrier.

places great emphasis on territorial advantage. The heart of the game is Camp's rule. Devised by Yale University coach, Walter Camp, it states that a team retains possession of the ball only if it can advance it 10 yards in four successive plays, or downs. A match is divided into a series of downs, the ultimate object, as in rugby, is to get the ball over the opposing team's goal line.

Substitutions

However, the major difference between American football and other sports is that each team is allowed to make as many substitutions as it likes during a game – they may even change the whole 11 players. So most teams will have an attacking line-up – the offense – and a defending side – the defense – as well as specialists such as goal kickers. Usually the offense is deployed when the team has possession of the ball at a down and the defense is called on when the opposition have the ball.

Because so much of the game involves bone-crunching collisions, American footballers are heavily protected – deaths were not uncommon 100 years ago. Each player must wear regulation safety equipment, which includes a helmet,

Mike Powell/Allsport

Joe Lawrence

THE PHYSICS OF COMBAT

PROTECTIVE ARMOUR

THE DANGER TO THE BRAIN

ROUGH STUFF

A FIGHT TO THE DEATH MAY not be the aim of modern contact sports but, like the gladiatorial spectacles of Ancient Rome, they still appeal to a deep-rooted desire for confrontation. And, in spite of strict safety regulations, today's gladiators face an ever-present threat of serious injury – even death.

These are the sports where deliberate physical contact is not only allowed but is encouraged as an important part of the play. They include team sports, such as rugby, American football and ice hockey, and also individual sports such as boxing, wrestling and the martial arts.

It is a well proven scientific principle that an object of larger mass will always dislodge a lighter object. So a large sportsman should always overcome a lighter one.

Size and weight

To minimize the advantage given by size, individual contact sports such as boxing are regulated into weight divisions, so that a flyweight (50 kg) is not in the ring with a heavyweight (over 90 kg), which would be both unfair and very dangerous.

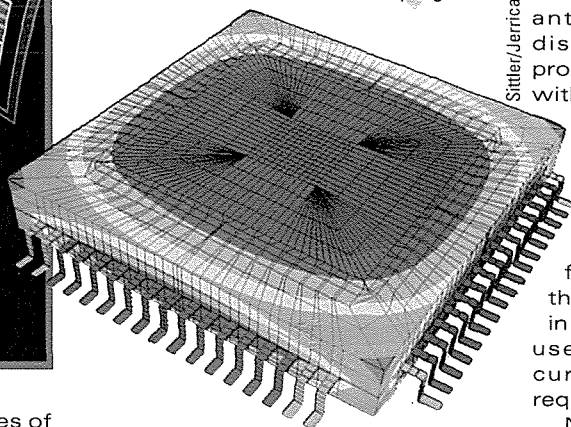
Boxing is the most lethal of all contact sports: in spite of strict safety regulations, more than 100 professional boxers have died during the last 30 years.





Designing a chip, or integrated circuit, using a light pen. Software engineers are always striving to make computers easier to use.

Computer graphics can be generated in three dimensions and in full colour using the latest graphic-design programs.



Sittler/Jerrican

or trojans may be planted in computer systems to cause mischief or damage. These may lie undetected for weeks before being triggered off (see PLANET EARTH pages 91-92).

There are now a large number of anti-virus programs, called disinfectants or vaccines, and programmers are seeking to keep up with new viruses, and even get one step ahead.

Another major task facing software engineers today is how to make computers simpler for everyone to use.

Operating systems increasingly feature a user-friendly interface that sets out the options available in the form of pictures, or icons. The user simply positions a flashing cursor on the screen over the required function.

New developments include 'earcons' that provide audible as well as visual cues to the user. Already some computers can be voice activated using a special headset, and screens that can now be operated at the touch of a finger.

each flow chart step into a series of instructions in computer language.

The computer user will usually buy a disc or tape containing an application that suits his own needs, such as word-processing, accounting or graphics. But if there is no

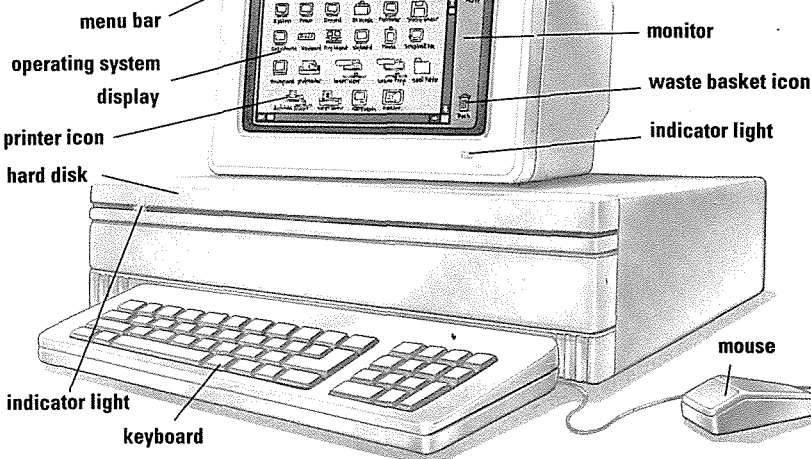
Apple Macintosh and PC 'windows' computers employ a system of icons on the monitor screen to make them more user-friendly.

COMPUTER TIME-BOMB

In December 1989, between 10,000 and 20,000 copies of a program purporting to offer advice on the disease AIDS were mailed to owners of IBM personal computers across the UK. Hidden inside the program was a 'trojan' - a piece of software intended to destroy data and other files held on disc. The program's distributor threatened to withhold instructions on how to stop the trojan from doing its dastardly work unless users sent between \$180 and \$370 to a mysterious address in Panama. The plot was foiled with minimal damage done when a public warning was put out, and eventually an American medical computer consultant was arrested and charged.

Apple Macintosh/John Houghton

Desktop Computer



ready-made package that fits the bill, the user can attempt to develop his own software. This involves either writing his own programs, which can be complicated and time-consuming, or calling in a specialist software developer, who will tailor a program to the user's requirements.

Bugging problems

Software developers are often used by those businesses that need to keep a large database with a list of clients or customers. Specialized software can allow them to link different types of file, such as addresses, and invoices together with data on stock control.

With any type of program, the software engineer's job does not finish when it is written. Because computers are so sensitive, and can contain huge amounts of information, much of a

programmer's time is taken up with developing fail-safe devices.

Even the slightest mistake or 'bug', such as a missing comma, is enough to make a whole program fail. For this reason, debugging is a vital part of software development. In some cases, undetected errors can have catastrophic results. On 3 June 1980, for instance, three separate bugs in the USA's computerized early warning system signalled that a Soviet nuclear attack was under way. Fortunately, the problems were spotted in time to avert a full-scale, nuclear counter-strike.

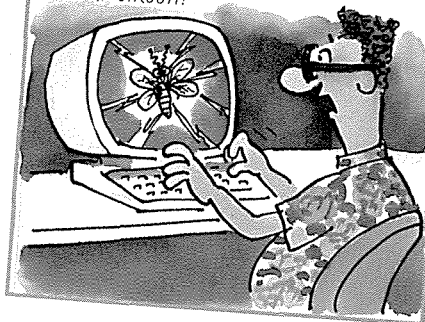
Trojan horses

Another major challenge facing software engineers is how to overcome deliberate computer vandalism, or hacking as it is sometimes known. Harmful programs known as viruses, worms

Just amazing!

BUGS IN THE SYSTEM

BUGS WERE NAMED AFTER A REAL INSECT. WHEN AN EARLY COMPUTER GAVE STRANGE RESULTS, ENGINEERS TOOK IT APART AND FOUND THAT A MOTH HAD CAUSED A SHORT-CIRCUIT!



Paul Raymond



SOFTWARE DESIGN

COMPUTERS ARE ONLY DUMB machines by themselves. But fed with programs of specially coded instructions they can solve an incredible range of problems at great speed. The brains behind the programs are the programmers — or software engineers as they are known.

These programs, known as software, exist in a number of different forms. For example, an operating system is vital to start up the computer. Applications software, on the other hand, consists of those programs that tell the computer how to solve a particular problem. This may range from playing a simple arcade game to calculating the path of a spacecraft

to Mars.

Applications are usually written in a 'high-level' computer language, such as BASIC, which stands for Beginners' All-purpose Symbolic Instruction Code.

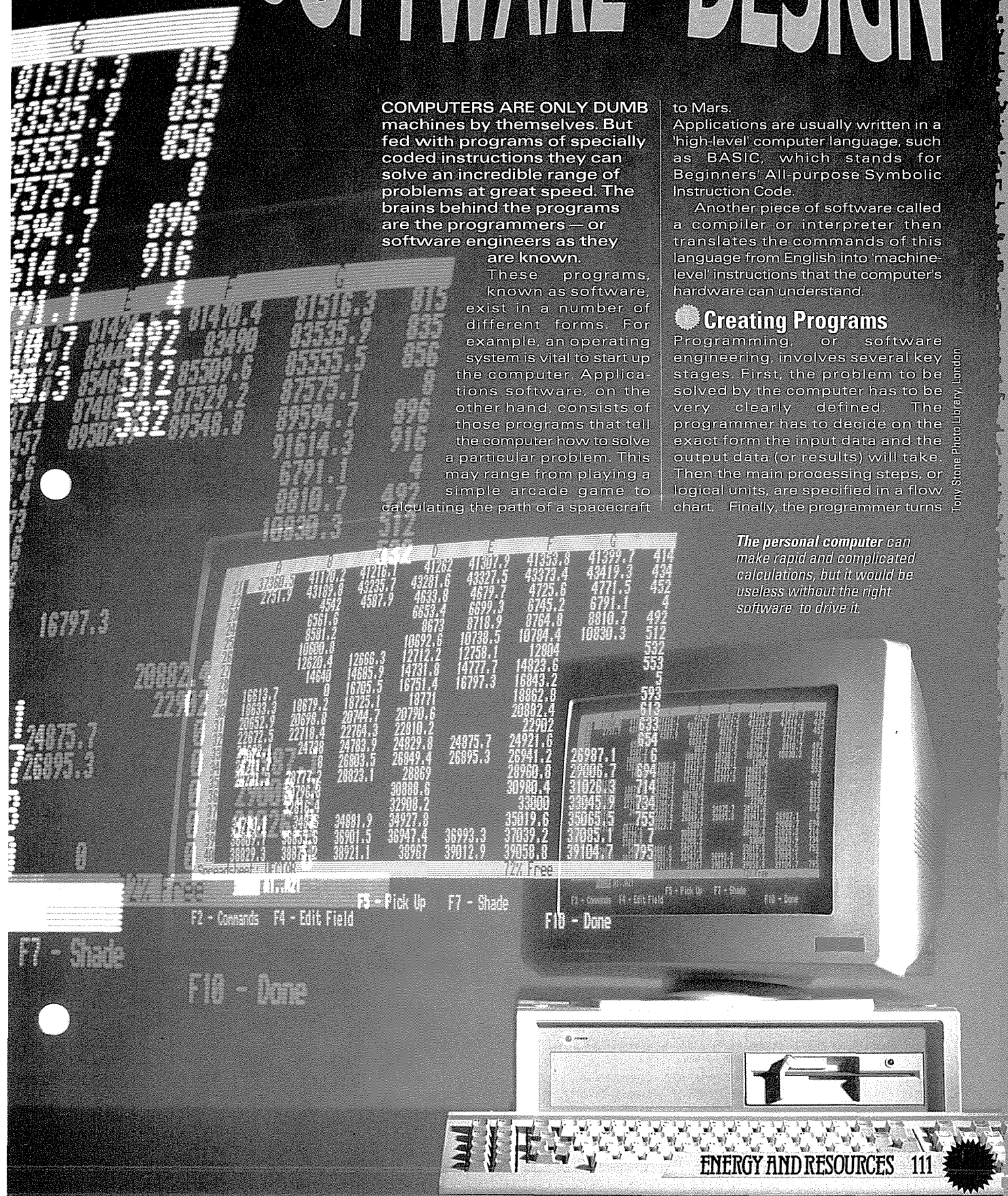
Another piece of software called a compiler or interpreter then translates the commands of this language from English into 'machine-level' instructions that the computer's hardware can understand.

Creating Programs

Programming, or software engineering, involves several key stages. First, the problem to be solved by the computer has to be very clearly defined. The programmer has to decide on the exact form the input data and the output data (or results) will take. Then the main processing steps, or logical units, are specified in a flow chart. Finally, the programmer turns

Tony Stone Photo Library, London

The personal computer can make rapid and complicated calculations, but it would be useless without the right software to drive it.



equipped with giant vibration needles each capable of delivering an impact force of about 120 tonnes to the seabed. Such devices are very efficient and lubricate the entry of the needles into the seabed – to depths of 15 metres – by means of jets of air and water. *Mytilus* had a modular construction consisting of five pontoons. The main one was

assembled using one of the world's largest floating cranes.

Battering against parts of the coast where rocks are soft, the sea can rapidly eat away land, destroying property and valuable farmland. To fight back, engineers have come up with a variety of designs for sea walls and defences:

- vertical walls are the simplest to build, but not the most effective.
- curved sea walls throw the waves up and back on themselves but increase beach erosion so that the wall is undermined and may eventually collapse
- new designs, which aim to absorb the energy of waves and so weaken their destructive force are the most successful. A honeycomb-shaped sea wall at Felixstowe in the UK, for instance, absorbs roughly half of the waves' energy and is expected to last for at least 50 years

Canary Wharf in London's Docklands is part of a massive development that has transformed the derelict waterfront.

Olympia & York/Canary Wharf Ltd

FROM THE ASHES



London Docklands Development Corporation

Land need not necessarily be 'reclaimed' from the sea. This artificial ski slope at Beckton Alps is part of London Dockland's development programme. It is built on a former slag heap and is an example of wasteland being put to good use.

has to be flushed, several times if necessary, by flooding the land with fresh water to reduce its salinity.

In delta areas such as the Rhone in France, and the Mississippi in the Gulf of Mexico, new land is continually being formed by deposition.

Deposition

Silt eroded from further upstream is carried to the delta of the river. There it falls to the river bed as the water speed drops. Here the problems of reclamation can be especially difficult because, through time, rivers may change their courses quite unpredictably. When this happens, the loose, soupy marsh of the abandoned delta, cut off from the river's fresh water and silt, may simply sink under its own weight.

The Eurotunnel reclamation project makes use of jack-ups (movable platforms) from which cranes and other equipment can work. The jack-ups have legs that can be adjusted to keep pace with the sea wall as it grows higher.



QA Photos, Hythe, Kent

surrounded by four smaller pontoons that could be disconnected when the vessel had to be moved through locks to other work locations.

After the soil was prepared, millions of square metres of sand and gravel mattresses were laid down to protect the seabed from erosion. Layers of stony material, also compacted, formed a base for the barrier piers.

Sea defences

A third vessel lowered the 18,000-tonne supporting piers of the dam into place. Each pier stands 40 metres tall – about the same height as a 13-story building. In total they contain enough concrete and steel to build a town to accommodate about 30,000 people. The rest of the structure was

● a dynamic breakwater designed in the USA is even more advanced. It consists of an array of floats tethered just below the surface of the water that drastically reduces the energy of the waves on impact, before they reach the shore.

Salt marshes

Low-lying coastal plains are the chief battlegrounds between the sea and the land. In eastern parts of the UK, salt marshes, constantly invaded by the sea, were reclaimed for use as agricultural land long ago. Drainage ditches allowed the salt water to be drained off, while protective embankments, like the great shingle ridge of Dungeness around Romney Marsh in Kent, stand guard against further incursions by the sea. Finally, to make the reclaimed soil fertile it

Just amazing!

BEACH BLAST

EVERY DAY, OCEAN WAVES POUND THE WORLD'S SHORES WITH AS MUCH ENERGY AS A 50-MEGATON NUCLEAR BOMB.



Paul Raymonds

Eastern Scheldt comprises 45 sq km of vegetated mudflat, 26 sq km of shallow water and 24 sq km of deep water. The area teems with wildlife and provides one of Western Europe's major wintering grounds for waterfowl. Lobster, oyster and mussels are bred there and many species of shrimp and fish use the waters as a nursery ground.

Previous artificial efforts to protect the shoreline have had the side-effect of creating clear waters. This and the relatively high local temperatures have combined to encourage the proliferation of species of marine life normally found much further south.

Rather than sealing off the Eastern Scheldt with a solid dam, a storm-

surge barrier with huge steel gates was built. The gates are operated by hydraulic rams and can be closed when storms are forecast, and left open at other times to preserve the natural ebb and flow of the tides. This, the largest dam of the Delta Project, was completed in 1986.

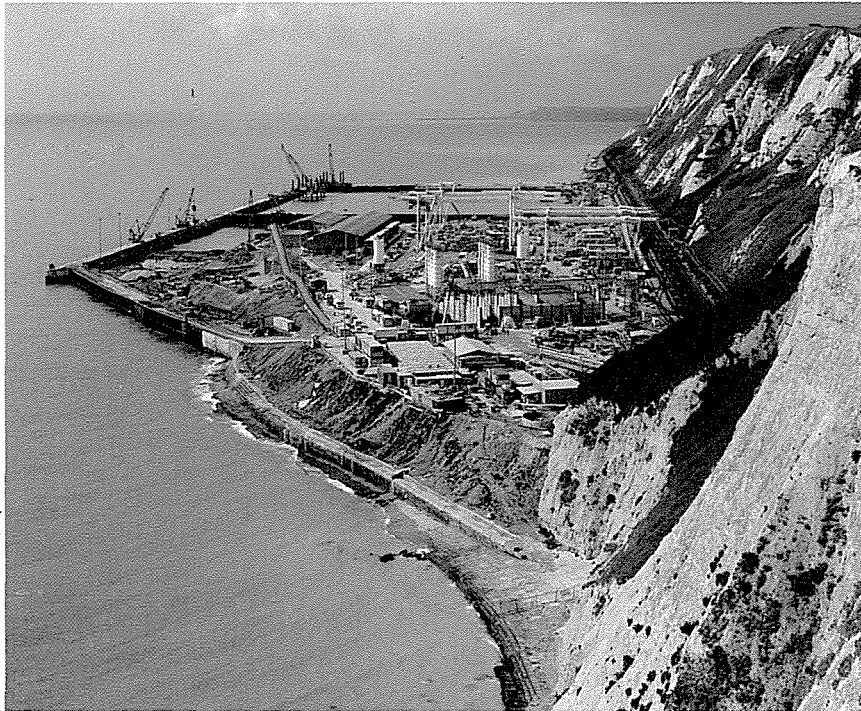
Compacting the bottom

Revolutionary engineering and an extraordinary fleet of construction ships were used for this project. To prepare for the enormous weight of the structure, the sandy bottom of the Eastern Scheldt had to be compacted. This was to prevent strong tidal currents in the area washing away the sand from the base of the dam. Compacting 25,000 sq metres of sea bed, 20 metres below the surface of the sea where strong tidal currents flow over highly porous sands (with an uncertain load-bearing capacity) was a formidable task.

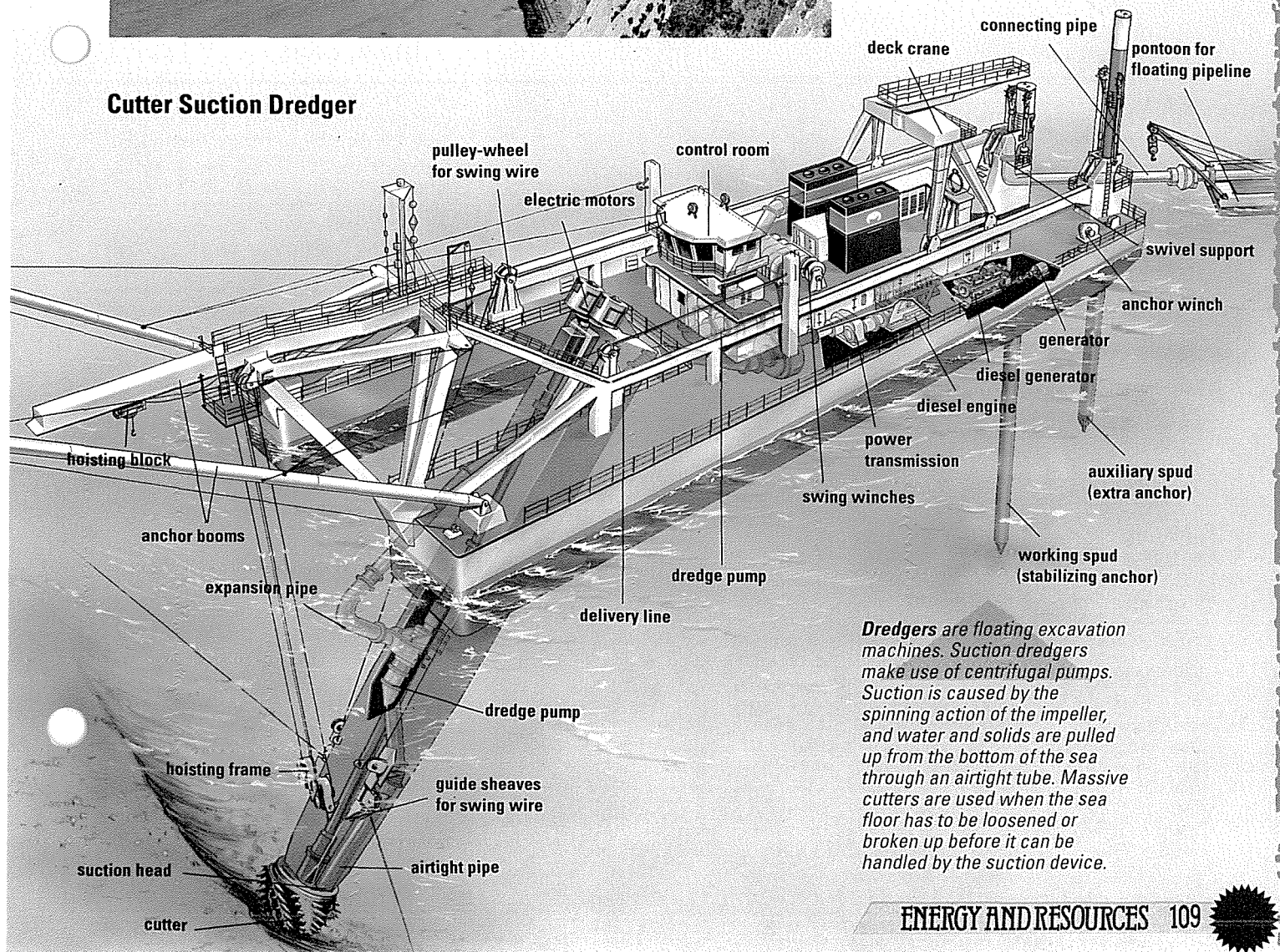
A vessel was specially designed to do this job. The *Mytilus* was

Excavation spoil from the English end of the Channel Tunnel was used to build a platform under the White Cliffs of Dover. The land will be used for recreation.

QA Photos, Hythe, Kent

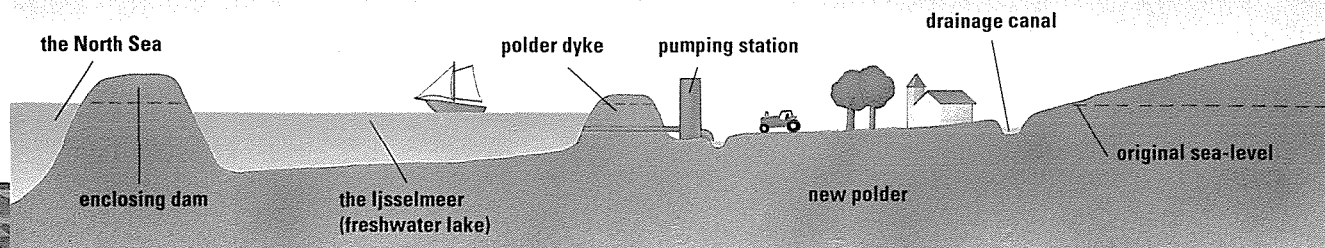


Cutter Suction Dredger



Dredgers are floating excavation machines. Suction dredgers make use of centrifugal pumps. Suction is caused by the spinning action of the impeller, and water and solids are pulled up from the bottom of the sea through an airtight tube. Massive cutters are used when the sea floor has to be loosened or broken up before it can be handled by the suction device.

Cross-section of a Dutch Polder



A land area of 2250 sq km –over twice the area of Hong Kong –has been reclaimed from the original Zuiderzee bay in Holland.

The enclosing dam is built first to separate the sea from the freshwater lake that builds up behind it. A dyke is then built and water is pumped from its land side into the lake. Drainage canals help the new polder to dry out in about five years.

The Eastern Scheldt barrier has 62 gates that remain open except when flooding threatens. This serves to protect the wildlife of the IJsselmeer that depends on tidal movements.

over this densely populated nation.

In the north of the country, a large shallow bay called the Zuiderzee proved to be the biggest challenge. The world's longest sea dam, the Afsluitdijk (or Great Dyke), was built across the mouth of this bay. Completed in 1932, the dam spans a total of 32.5 km. It has a width at sea-level of 89 metres and is 7.5 metres high measured from the sea bed.

Keeping land dry

Behind the Great Dyke, the salt water has been drained and replaced by a shallow freshwater lake, the IJsselmeer, fed by inflowing rivers. In the past few decades, five large polders within the IJsselmeer have

been reclaimed. This has been done by constructing dykes around the reclamation sites, then building drainage systems to keep the polders dry. Pumping stations work continuously, drawing water from the surface soil and channelling it away through canals. The largest of the five polders, the Markerwaard, covers 603 sq km, while the total

reclaimed land area in the old Zuiderzee bay amounts to 2,250 sq km. Plans to add a further polder to the IJsselmeer have been opposed because wildlife will be disrupted by further reclamation.

The Delta Plan

The Afsluitdijk withstood one particularly devastating storm in 1953, but south, in Zeeland, at the delta area formed by the Rhine, Scheldt and Maas rivers, 1800 people were drowned and much land was flooded. To prevent such a tragedy happening again the Dutch came up with the 'Delta Plan'. This ambitious project, completed in 1986, linked the islands of Zeeland to the Dutch mainland.

Wildlife considerations

The barriers were constructed in increasing order of size so that the experience gained on the smaller ones would help the engineers with the larger barriers.

As work progressed plans were revised, in order to take account of environmental considerations. The

Netherlands Board of Tourism

This honeycombed sea wall, on the Lincolnshire coast in the UK, helps guard against erosion and flooding. A rock-filled embankment is armoured with large, interlocking, hexagonal, concrete blocks called 'seabees'. This structure absorbs more of the force of the crashing waves of the North Sea than a solid wall.



National Rivers Authority



Living on a polder – on some of the 40 per cent of reclaimed land in the Netherlands – has distinct advantages.

Ivaldi/Jericoan

- Q RIVER DELTAS
- Q BREAKWATERS
- Q HYDRAULIC DAMS

RECLAIMING THE LAND



World View/Science Photo Library

TIDES AND CURRENTS constantly change the Earth's coastlines, eroding in one place, depositing silt and shingle in another. For centuries, Man has attempted to combat the oceans by reclaiming tracts of land.

All over the world coastal marshlands have been drained and turned into rich agricultural land. Where the tide is especially high, or powerful storms are frequent, sea walls are erected to protect the coastline from erosion.

The Dutch, through necessity, are

the most experienced reclaimers of land in the world. Much of their country is flat and low-lying. It is also overcrowded. Over 15 million people inhabit an area of just 33,935 sq km – less than one-sixth the size of the UK. In the Netherlands, roughly 40 per cent of the country would be flooded at high tide if it were not for huge artificial barriers.

Polders

As early as the 12th century, the Dutch people began reclaiming stretches of land (called polders) from below sea-level. These early

The IJsselmeer is an enormous lake protected by a great dyke (seen as a thin white line in this satellite photograph). Within the dyke, five polders have been reclaimed. These show as distinctive field patterns with large amounts of blue in them.

efforts involved building earth dykes and draining off seawater with windmill pumps and a network of ditches. Modern projects are much more advanced, and today 1,300 km of dykes and dams prevent the North Sea from washing twice daily

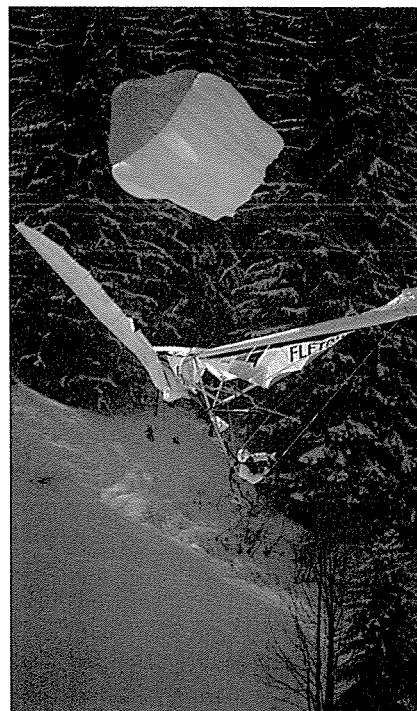
person into a package about 7 metres long with a diameter of roughly 20 cm. The pilot can then fit the glider together and strap him- or herself in ready for flight.

To get airborne, the pilot generally has to run at least 10 metres towards the edge of a steep slope into the wind. At

Five years later, he broke the hang-gliding distance record when he covered 488.19 km in a flight from Hobbs Airport, New Mexico, to Elkhart, Kansas.

There are limitations to practising the sport – a strong wind and a suitable hill site are not always easy to find. A powered hang-glider, equipped with an engine the size of an elongated outboard motor, overcomes these restrictions to some extent. As an engine makes the glider

Hang-glider pilot Pascal Morel made a celebratory flight in 1986 to commemorate the 200th anniversary of the first ascent of Mont Blanc in the French Alps.



F Rickard-Ardia/Allsport

the same time, the craft's nose has to be raised slightly. As the airflow increases, the sail is filled and the hang-glider lifts off the ground. The pilot shifts his weight forward to gain speed by pulling in on the control bar.

To make the hang-glider rise, fall or change direction, the pilot simply shifts his body. Moving his weight back slows the glider down by raising its nose. Leaning forward inclines the pilot's body and the wing closer to the horizontal, thus decreasing resistance to the wind and increasing speed.

Hang-gliding records

Experienced pilots, taking advantage of powerful updrafts in mountainous regions, travel remarkably high and far. In 1985, American hang-glider pilot Larry Tudor reached a height of 4,343 metres above his take-off spot.

less easy to control, some powered hang-gliders also have a wheeled undercarriage for greater stability. Hang-gliders have already been used instead of aircraft in aerial photography and many more roles will be found for them in the future.

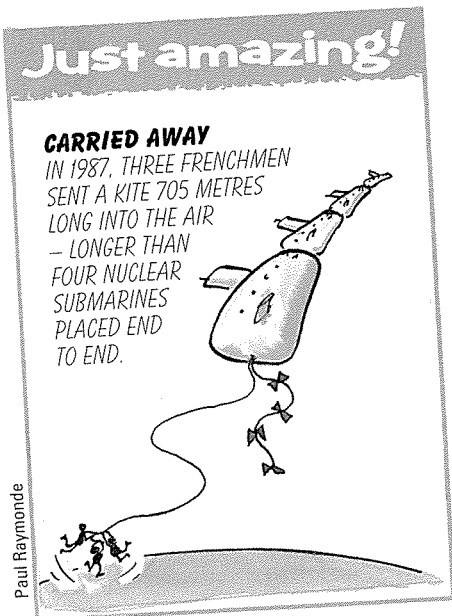
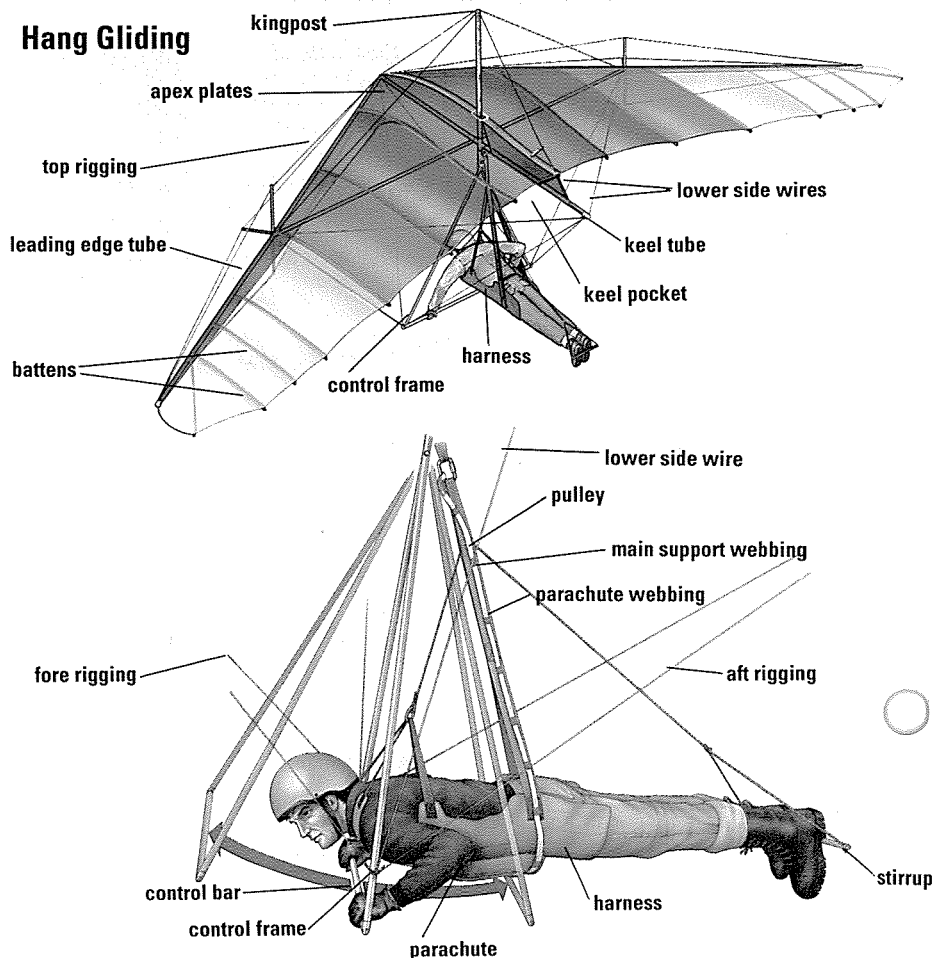
The pilot uses a bar to control a hang-glider. Pushing the bar forwards tilts the craft up at the front and slows it down. Pulling the bar back has exactly the opposite effect.

Great escape: in 1987 Pascal Plante's hang-glider collided with a balloon. Despite falling 800 metres, he survived.

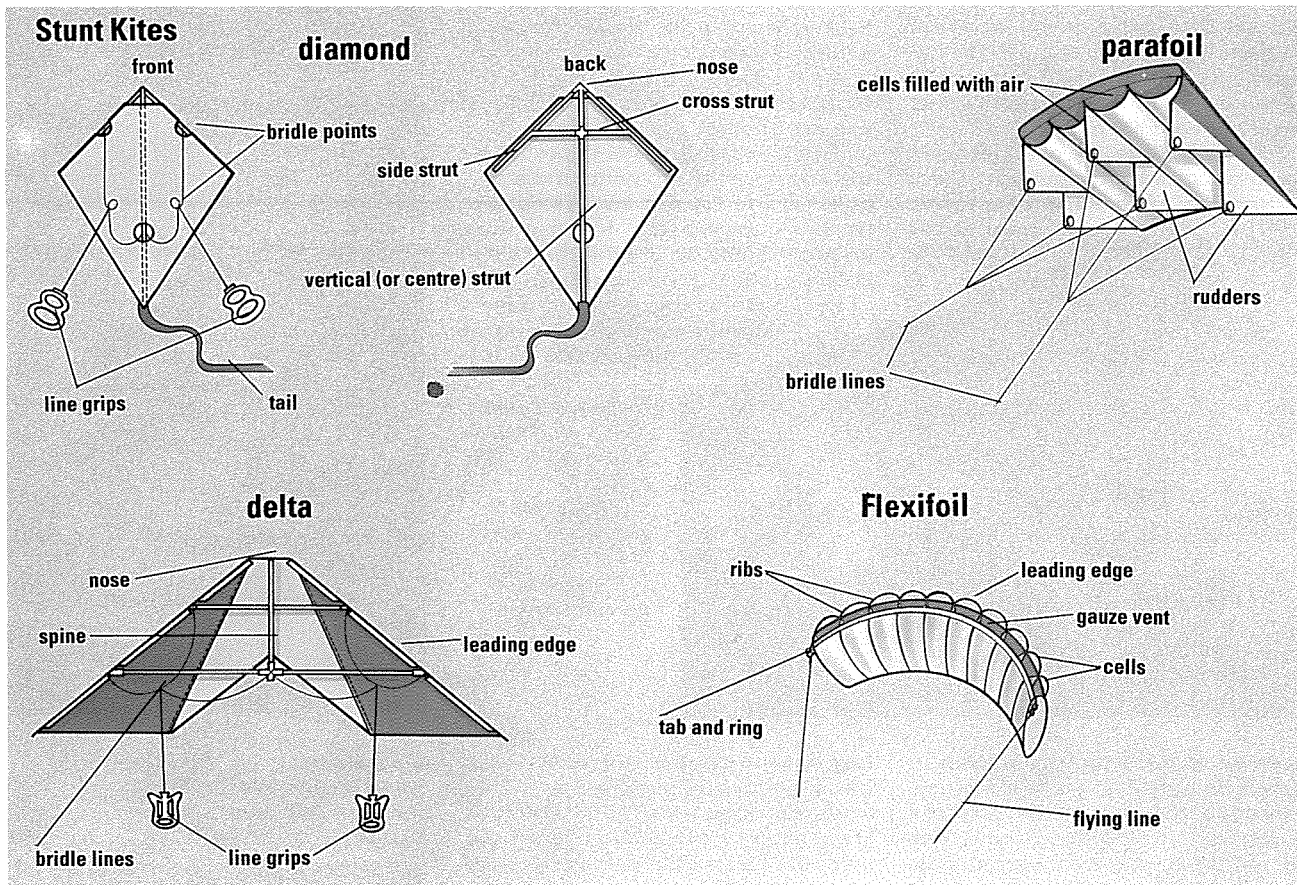
UPWARDLY MOBILE

Insects are sometimes sucked into thermals – in some parts of the world greenfly can be seen rising into the air on hot days. In experiments, fine nets towed behind aircraft caught insects at heights of up to 500 metres.

Hang Gliding



Paul Raymond



Matthew White

glider up again. For climbing in thermals the wings need to be long, giving a low rate of sink, but for gliding between thermals shorter wings that allow high-speed flight are better. The SB-11 glider overcomes this problem by having wings that can be lengthened by flaps that extend up to 25 per cent in flight.

Down to Earth

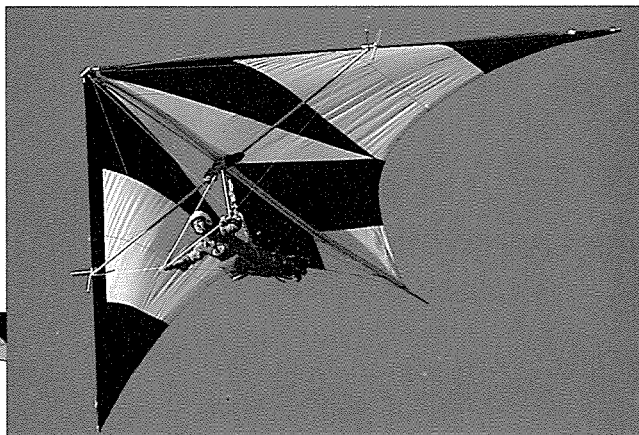
As it comes in to land, the glider may brake by releasing a small parachute that drags behind it. This enables it to land in a restricted space, such as a small field. Most gliders are also fitted with air brakes. The glider touches down on one wheel located below the cockpit.

Gliders can seat one or two

people; two-seaters are often used for training pilots. In the cockpit are a range of flying instruments, including an airspeed indicator, an altimeter and a variometer to show vertical rise and sinking speeds. Additionally, a glider often carries oxygen equipment, a radio and even a computer

High in the sky the silence is striking, but air currents can make it a bumpy ride. Padded clothing, protects the pilot (below) from freezing cold temperatures at high altitudes.

'Stunters' have two lines, giving a kite-flier tight control over them as they climb, dive and swoop in the air. A delta has a similar design to a hang-glider's wing. The cellular pockets on Flexifoils and parafoils provide lift by filling with air in flight.



Eric Crichton/Bruce Coleman Ltd

to track thermals and calculate optimum flying speeds.

The hang-glider, invented by NASA scientist Dr Francis Rogallo in the 1960s, is built and shaped more like a giant kite than an ordinary plane. The 'wing' is actually a triangular-shaped nylon sail stretched across a light aluminium frame. The pilot is suspended from the frame by a safety harness and steers the craft with a control bar.

A hang-glider pilot takes the glider, folded up, to the top of a hill. It can be folded down in 15 minutes by one

from Europe to Africa gather on the island of Gibraltar in the Mediterranean. The reason is that Gibraltar, being basically a naked lump of rock surrounded by sea, produces exceptional thermals. These allow the birds to soar effortlessly during the early part of the day and then to glide slowly down over the straits to the African continent.

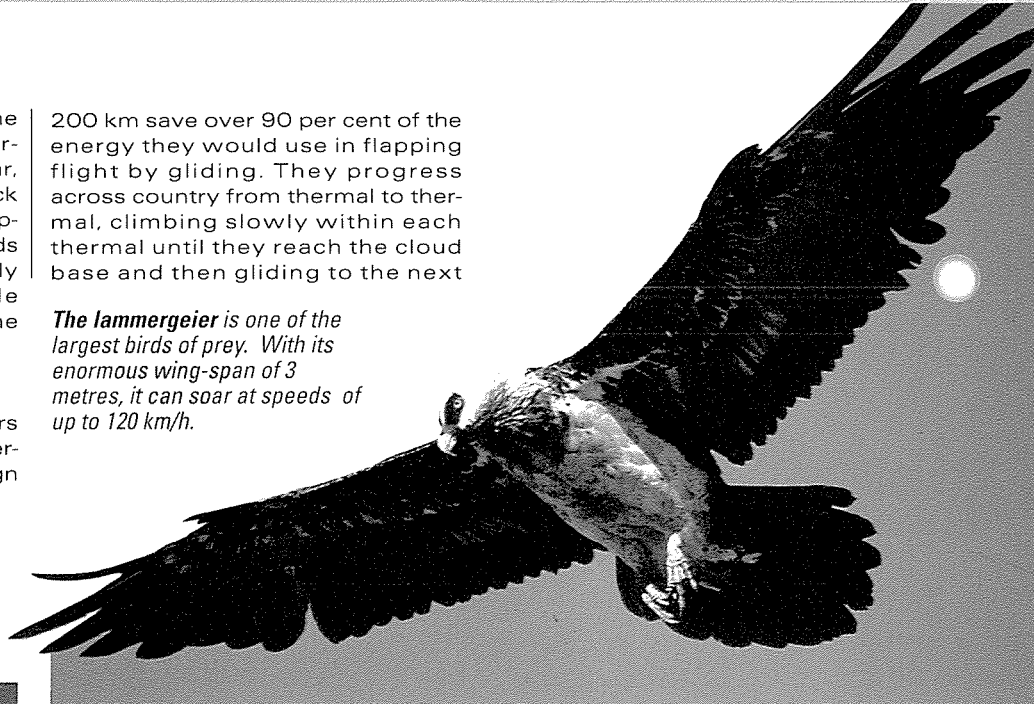
Thermal soaring

The pilots of gliders and hang-gliders learn to recognize places where thermals are likely to occur. One sure sign

A glider's wings are as slender as possible to reduce wind resistance (or 'drag').

200 km save over 90 per cent of the energy they would use in flapping flight by gliding. They progress across country from thermal to thermal, climbing slowly within each thermal until they reach the cloud base and then gliding to the next

The lammergeier is one of the largest birds of prey. With its enormous wing-span of 3 metres, it can soar at speeds of up to 120 km/h.



thermal in their line of flight.

A bird such as the albatross has long, slender wings that are highly efficient for gliding, since they provide good lift. The same type of wings are used on modern gliders. Materials such as plywood or fibreglass enable weight to be kept to a

the glider flies free. Another method is winch launching: the glider is launched into the air in a similar manner to a kite. One end of long steel cable is wound on to a powered drum and the other end attached to the glider. Once the cable is vertical, the pilot either lets it go or it is

Nigel Dennis/NHPA

PROFILE

WORLD GLIDING RECORDS

Longest distance in a straight line
Longest distance, out and return
Greatest height gain
Highest altitude reached
Fastest speed

Single-seaters

1460.8 km
1646.76 km
12,894 m
14,938 m
195.3 km per hour

Hang gliders

488.19 km
310.302 km
4343.4 m

is the presence of birds, such as gulls, wheeling around and around without flapping their wings.

The steep windward side of mountains and hills is another place where there are often strong updrafts as oncoming air is forced up and over the 'obstacle'. Eagles and cliff-dwelling seabirds as well as hang-glider pilots use these deflected air currents to gain altitude and prolong their periods of flight.

Vultures on a daily round trip of

minimum, while a narrow fuselage allows the glider to cut easily through the air.

As a glider or sailplane has no engine, it naturally needs assistance when taking off. It can be launched from a hilltop by a special catapult.

Taking off

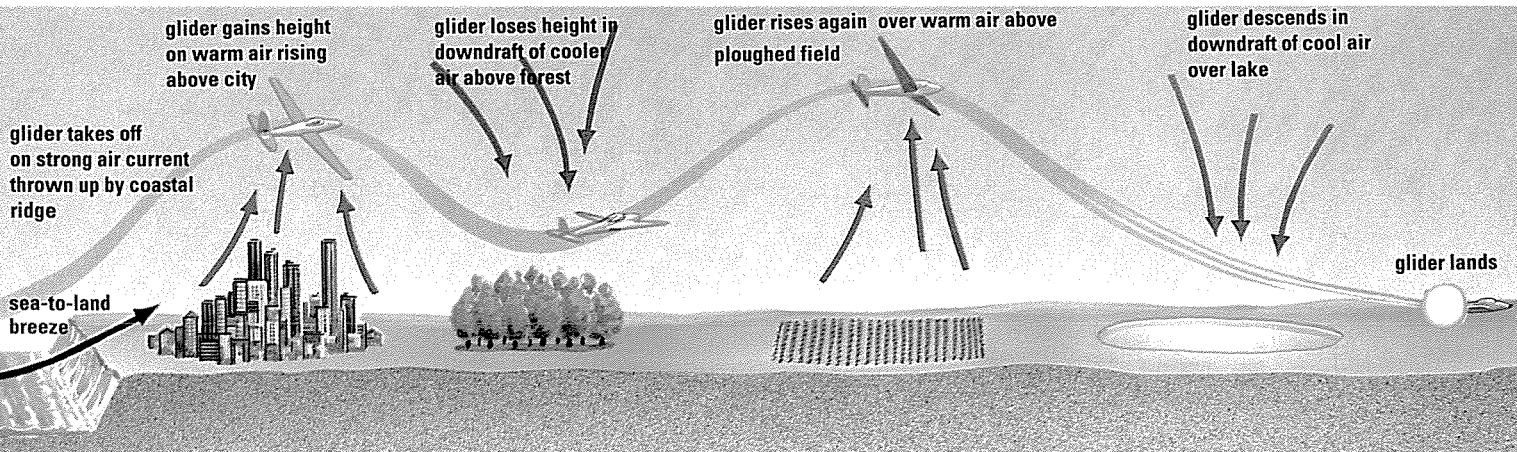
Normally, however, gliders are towed into the air behind a small plane. At an altitude of around 1,000 metres the tow cable is released and

automatically released.

After launching, the glider will slowly begin to drift downwards so the pilot looks for a thermal or air current where the rising air will carry the

Thermals – warm rising air – keep a glider airborne. Warm air rises above buildings and ploughed earth because these surfaces absorb heat from the sun more quickly than water or grassy and wooded areas.

John Carty



RIDING AIR

GLIDERS AND VULTURES have one important thing in common. They both rely on rising air currents to stay aloft.

Both birds and planes have wings shaped to provide lift as they move through the air. But that lift alone is not enough to overcome the weight of the glider (bird or plane). A bird flapping its wings or an engine-powered plane can generate enough additional lift to stay airborne by driving itself forward at higher speed. But a glider must gradually fall back to earth unless it can find an updraft of air. The trick is to know when and where such updrafts occur.

Bubbles of warm air

When the sun shines on land, more of its heat is absorbed by some parts of the ground than others. For example, exposed rock or ploughed fields will get hotter more quickly than a grassy or wooded area. The air above a warmer patch of land, in turn, becomes heated more rapidly than the surrounding air, so that it rises. Such a warm, upward moving bubble of air, called a thermal, is ideal for gliding.

Each September, many thousands of birds on their winter migration

The parafoil was invented by American Domina Jalbert. Made entirely from nylon, it gains its shape from the action of the wind entering openings on the wing's leading edge.

Tony Stone Photo Library, London

FROSTBITE – INJURY CAUSED BY EXTREME COLD



When skin becomes very cold, especially at the extremities of the body such as the hands and feet, the blood vessels inside it shrink and cut off the flow of blood. Gradually the affected area turns numb and changes from red to white to yellowish-grey. Because of the loss of feeling, the victim may not realise he is suffering from frostbite. Medical help must be sought for this condition. In mild cases, immersion in water of about 40°C is sufficient to restore circulation. But in severe cases, body tissues may be damaged beyond repair and may have to be amputated to prevent infection spreading.

Staying alive in cold seas and rivers poses one of the greatest of all challenges. In water of 0°C a person may survive for only 1 hour. A fat person will last longer than a thin one, having a greater resistance to the cold.

In water warmer than 20°C, swimming will increase the blood supply and keep the body warm.

Reserving heat

Swimming in water below 20°C is one of the quickest ways of losing body heat. Cold water flowing past moving limbs washes away the warmth created by increased blood flow. To try to keep warm, a person must stay as still as possible and

material, but is bulky. Where less bulk is required, man-made alternatives are available.

A synthetic fabric called *Gore-Tex*, for instance, has over a billion tiny openings per square centimetre. These 'pores' are so small that they keep out wind and rain while allowing water vapour from the body to pass through. This protects the wearer from bad weather on the outside, but stops condensation from building up inside the clothing.

Space blanket

Another man-made survival aid, the Space Blanket, is a very thin layer of aluminium bonded to a lightweight plastic sheet. The aluminium reflects body heat back on to the wearer while the plastic serves as

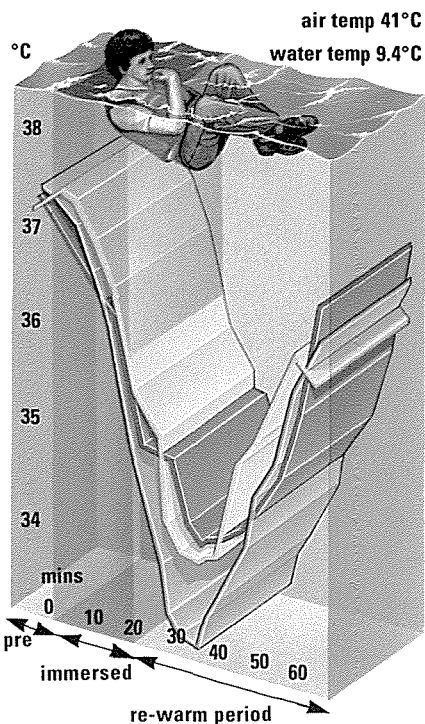
Foods for an expedition into inhospitable regions must be nutritious and, like other equipment, easy to transport.

Fats are high in calories and are hardest to find if the explorers are forced to live off the land so butter, lard or oil is important. Dehydrated meat blocks and chocolate are high energy foods. Salt is essential.



Body Heat Loss In Cold Water

internal temperature
radio pill
ear thermometer
rectal thermometer



an effective insulator. The only problem is that, not being porous, the Space Blanket tends to trap sweat as well as heat.

In addition to the cold, a shortage of oxygen poses problems at high altitudes. The body can be trained to adapt to a lack of oxygen for short periods – it increases the number of red blood cells that carry oxygen around the body. Climbers who do not train their bodies slowly and properly for high altitudes risk death from lung oedema – where tissue fluid is forced into the lungs.

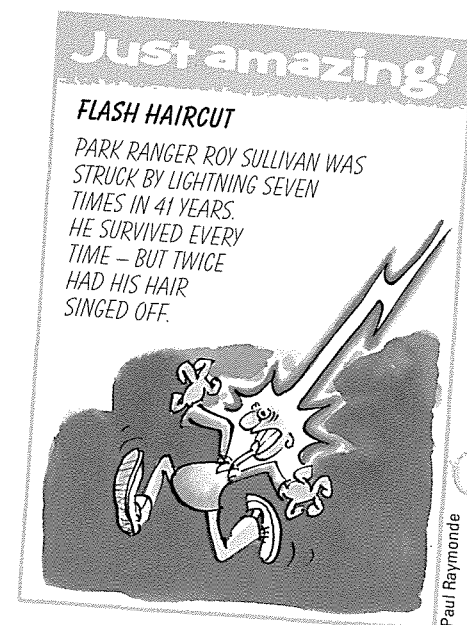
High altitudes

The highest point at which humans make permanent homes is 4,875 metres – in the Andes mountains in Bolivia. The local Indians who live higher than this claim to have to descend in order to conceive and have children.

Recordings from a swallowed radio pill, and from ear and rectal thermometers, show that the body takes time to regenerate heat after being immersed in cold water. After-drop (continued fall of body temperature after removal from cold water) can kill. **HELP** (The Heat Escape Lessening Posture, top) protects areas of high heat loss: the sides of the chest and the groin.

draw in his or her arms and legs.

In shark-infested water, sharks will be attracted by traces of blood or by weak, splashing movements. If threatened, a person should attempt to swim using strong, regular strokes, often changing direction suddenly since sharks cannot easily veer from side to side. As a last resort, a smart jab on the top of the snout may repel an attack.



Roger Mear/Remote Source

Paul Raymond

HYPOTHERMIA

DEHYDRATION

INSULATION

BRAVING THE ELEMENTS

UNPREPARED, IN THE WILD, Man is as defenceless as any other creature. Extremes of heat, cold and altitude are among the most dangerous hazards to be faced.

A person can survive for several weeks without food, especially if they are inactive. But if body salt is lost through sweating it must be

quickly replaced. Salt tablets are the easiest way to carry salt and can be quickly dissolved in water.

Without water, survival under the daytime desert sun is measured in hours. Even resting in the shade an adult must take in at least 1 litre of water a day to prevent dehydration. At 35°C, the basic requirement soars to 5 litres – much more if

moving or working strenuously.

Exposure to low temperatures poses different problems. To function properly, vital organs, such as the heart and kidneys, have to be kept at a constant temperature of about 37°C. If the body's 'core temperature' dips much below this, hypothermia sets in. The person shivers and breathes more slowly and heart rate is reduced in an effort to save energy. Hypothermia is dangerous to human life; however a similar process – hibernation – allows some animals to survive winter. Their metabolic rate slows and they are torpid for lengthy periods.

Protective clothing

In extreme cold, the right type of clothing is essential. Clothes should be worn in layers to trap air warmed by the body and the outer layer must be thickly insulated and waterproof. Eider or goose down remains the most effective insulating

The survival basics

– food, water, warmth and shelter – change in order of importance depending on where you are.

Water and shelter from the sun are of chief importance in the desert, while warmth and shelter take top priority in polar regions. This ski party (below) sit out a spring storm.

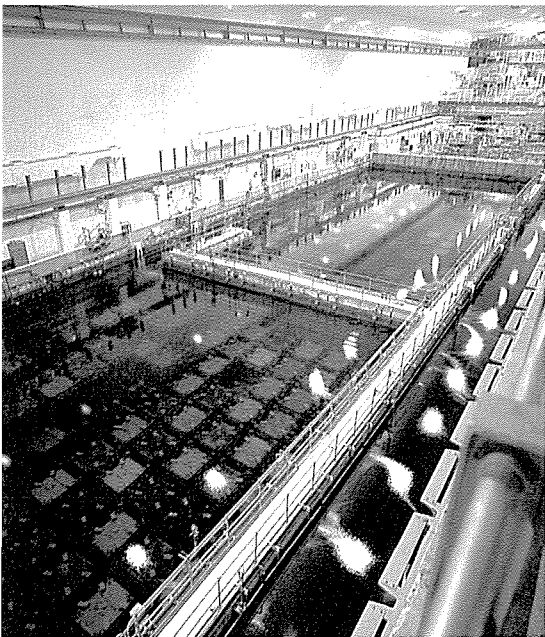
The nose plaster is a guard against frostbite.



Jim Lowther/Chameleon Television Ltd



John Cleare/Mountain Camera



Mere Words/SPL

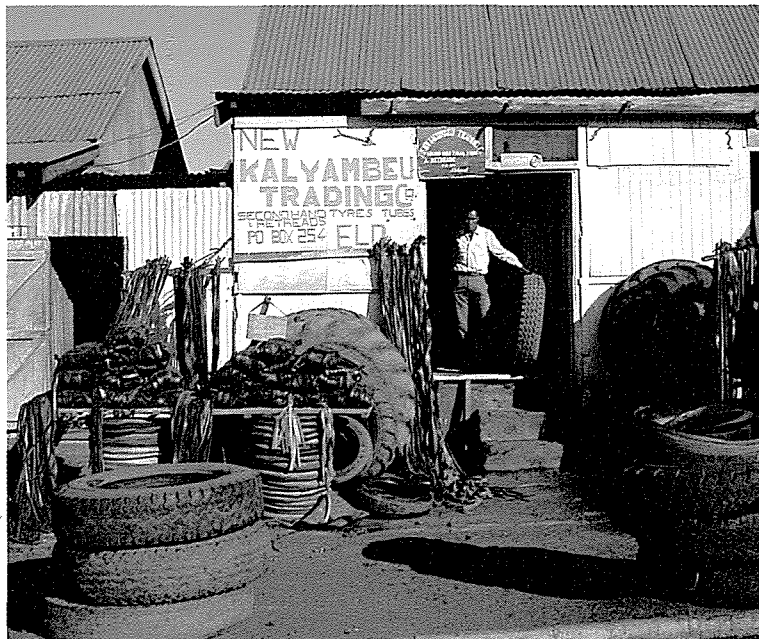
the recycling rate is over 50 per cent, but the rest of the world is lagging behind. In Britain people buy more than 6 billion aluminium drinks cans every year. Of these, only a quarter are recycled.

Aluminium recycling is highly cost-effective. It saves up to 95 per cent of the energy needed to produce the metal from raw materials. The cans

bituminous coal.

Some waste can be recycled to provide a source of energy. Animal waste contains energy that can be extracted in anaerobic digesters – large vats in which bacteria break down the slurry anaerobically (without the presence of air). This process produces methane gas, which can be tapped as a fuel.

Spent nuclear fuel is stored in cooling ponds before being separated into its constituent parts – 96 per cent is uranium that, after recovery, will be manufactured into new fuel.



PROFILE

RUBBISH

	Annual domestic waste (tonnes)	Equivalent per person (kg)
USA	200,000,000	875
Canada	12,600,000	525
Australia	10,000,000	680
Japan	40,225,000	344
W Germany	20,780,000	337
France	15,500,000	288
G Britain	15,816,000	282
Italy	14,041,000	246
Spain	8,028,000	214
Holland	5,400,000	381
Switzerland	2,146,000	336
Norway	1,700,000	415
Sweden	2,500,000	300
Denmark	2,046,000	399

Recycling materials does not always involve hi-tech reprocessing techniques – in Kenya old rubber tyres are cut into strips to make a cheap alternative to bed slats.

are melted down to produce ingots (piles of unwrought metal), which are then rolled into sheets ready to be moulded into new cans.

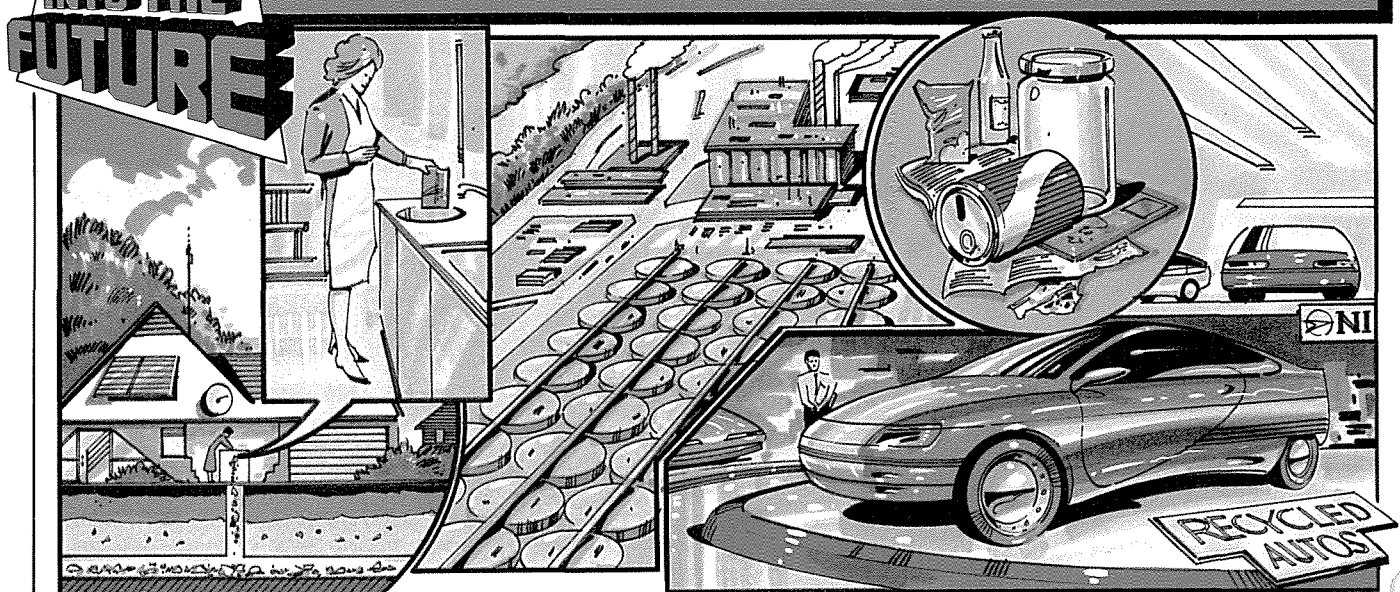
Waste from the coal-burning industries, in the form of fly ash, can be used in the manufacture of cement and concrete building products. The ash is recovered from the flue gases of chimneys burning

In China, huge digesters are built underground. In 1981 China reported to the United Nations that there were over seven million biogas digesters in the country, mostly in the Szechwan Province, which provided a supply of methane gas to around 30 million people and 150 methane-fired power stations.

Margaret Murray/Hulton-Don Library

INTO THE FUTURE

WASTE DISPOSAL WITH NO WASTE

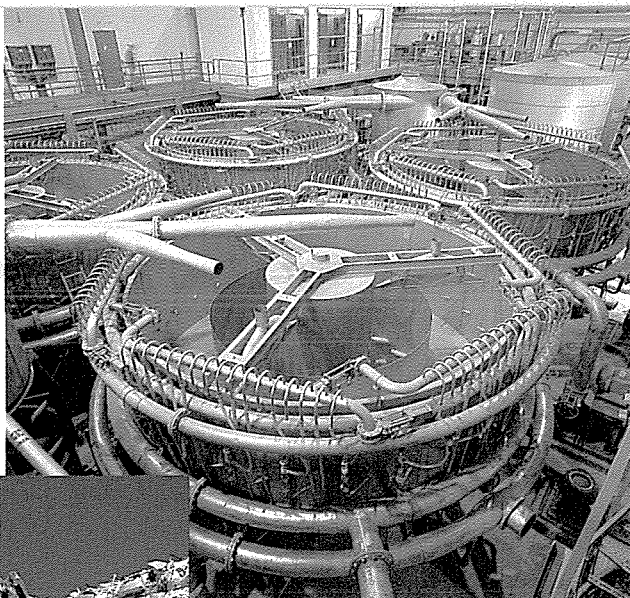


▲ Future homes will be equipped with 'refuse centres' linked to a 'refuse mains' system, which will whisk away all household refuse to out-of-town plants.

▲ Here, programmed automatic sorting machines will separate all reusable material from unusable refuse – this will be used to fuel generators.

▲ All reusable materials will be automatically sent to a reprocessing plant that will be able to create new raw materials for manufacturers.

A de-inking vat where air and soap are added to the paper 'porridge'. Ink particles cling to the foam and rise to the surface where they are vacuumed up. Paper of all colours is easy to recycle (below), but only a quarter of waste paper is reused.



Bridgewater Paper Co

duce high quality recycled paper.

The used paper is de-inked, then put into a chemical bath to separate the fibres. Water is blended with the mixture to produce a kind of porridge, which is passed through a sieve to remove any staples. The fibres are then pulverised in a refiner. This 'stock' is poured on to a moving plastic mesh which, along with a vacuuming process, drains off the water, leaving behind a layer of fibre that is compressed by rollers. The resultant fibrous web is further dried by steam-heating.

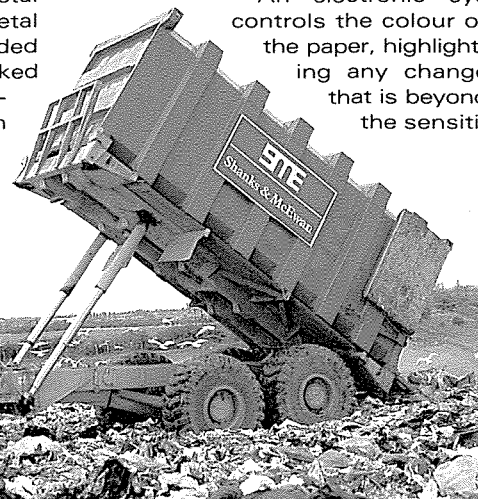
Computer control

The modern paper-making process differs significantly from traditional techniques in the use of X-rays infrared sensors and computer control. All of these are used to monitor the quality of paper in terms of its thickness, weight, water and mineral (chalk or china clay) content.

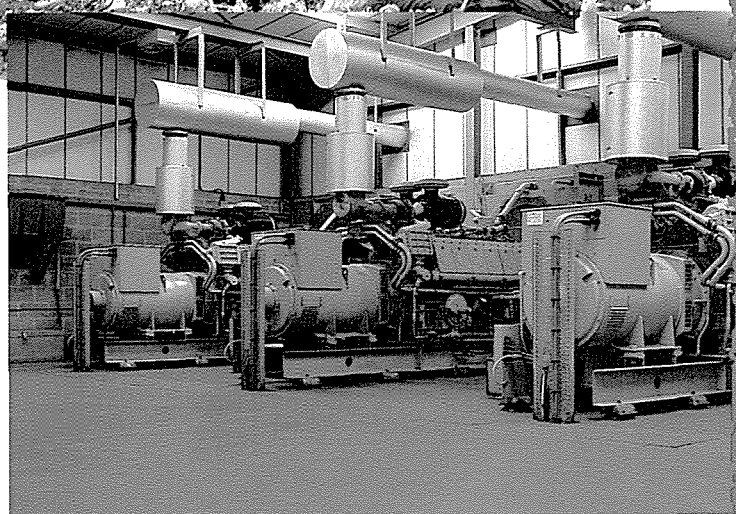
An electronic eye controls the colour of the paper, highlighting any change that is beyond the sensi-

the ground plastic into a bath filled with water in which the PET sinks and the PVC floats.

The PET and PVC is separated, dried and put through a metal extractor that pulls out any metal neck rings. What is left is moulded into tiny flakes of resin and baked for six hours at 180 °C. This recrystallizes the plastic, which can then be sold as raw material for pipes, bottles (non-food



Rubbish may provide the energy of the future. Refuse, covered with a mixture of artificial and real soil, releases highly combustible methane gas. In Bedfordshire, England, electricity generators (right) are fuelled by landfill methane gas.



Shanks & McEwan (Southern) Ltd

type) and thermal fillings for clothes.

Recycling paper has become a major concern today, if 75 per cent of waste paper and cardboard was used to make new paper, about 35 million trees could be saved each year. In the past, recycled paper was often a greyish, rough-textured material. New techniques have recently emerged, however, to pro-

duce high quality recycled paper. The used paper is de-inked, then put into a chemical bath to separate the fibres. Water is blended with the mixture to produce a kind of porridge, which is passed through a sieve to remove any staples. The fibres are then pulverised in a refiner. This 'stock' is poured on to a moving plastic mesh which, along with a vacuuming process, drains off the water, leaving behind a layer of fibre that is compressed by rollers. The resultant fibrous web is further dried by steam-heating.

Used aluminium cans are one of the few waste products from which all of the scrap material can be reprocessed to make new cans identical to the old ones. In the USA

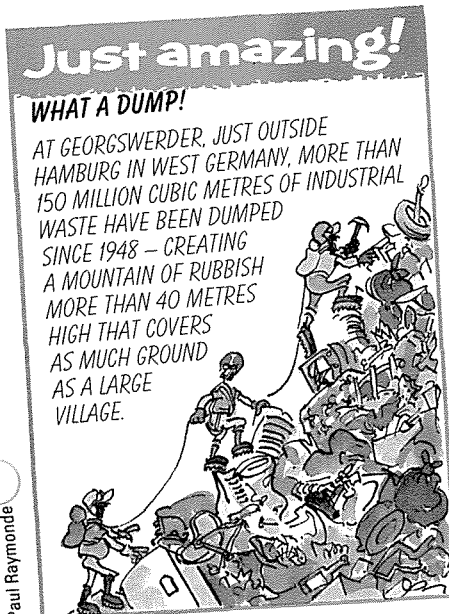


process of sorting and cleaning. Initially they are sorted by colour – the clearer this is, the higher the value of the plastic.

Water bath

The sorted bottles are ground up, washed with water and solvents to extract dirt and glue, then split into PET (polyethylene terephthalate, which comprises around 70 per cent of the plastic) and PVC (polyvinyl chloride). This is done by pouring

Shanks & McEwan (Southern) Ltd



Just amazing!

WHAT A DUMP!
AT GEORGSWERDER, JUST OUTSIDE HAMBURG IN WEST GERMANY, MORE THAN 150 MILLION CUBIC METRES OF INDUSTRIAL WASTE HAVE BEEN DUMPED SINCE 1948 – CREATING A MOUNTAIN OF RUBBISH MORE THAN 40 METRES HIGH THAT COVERS AS MUCH GROUND AS A LARGE VILLAGE.

Paul Raymonde

Spectrum Colour Library

Vehicles are also useful in providing lead — this is found in car batteries. Battery plates are smelted to produce lead for new batteries.

Rubber from the thousands of tyres worn out on the roads can be recycled to produce valuable chemicals. This involves heating the tyres and reclaiming a liquid oil that can be used in the manufacture of other chemicals, a gas which can be used as a fuel, and a carbon-based residue useful for building roads.

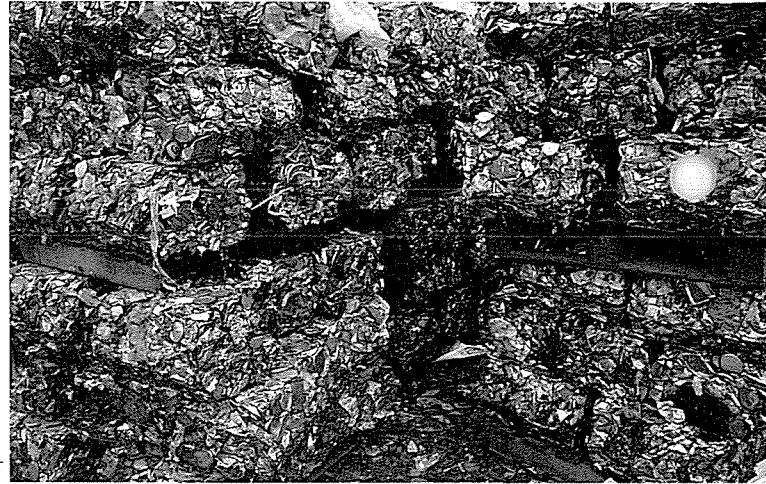
X-ray film

Silver, one of the more valuable metals, is used in the X-ray film and photographic paper industries. It evaporates during the production of the film and paper. The gas is cooled by water sprays, then passed into an electrostatic precipitator that attracts the silver particles. The result is an almost total recovery of the silver. It is then recycled into the photographic paper production.

Aluminium is one of the most expensive metals to produce.

The energy required to make a single drink can is equivalent to half a can filled with oil. But recycling an old can requires only five per cent of the energy required to make a new one.

Spectrum Colour Library



also be used as an alternative to sand in building materials.

In the United States, where there are compulsory bottle deposit laws, plastic bottles are recycled. The bottles pass through an eight-stage

BIOLOGICAL PLASTIC

Unlike most rubbish, man-made plastics are very durable and do not decompose in the presence of bacteria. However, American scientists at the University of Massachusetts and Amherst have produced a biodegradable plastic from a strain of bacteria. Bacteria from the *Pseudomonas* strain is grown in an atmosphere without nitrogen. The bacterium will make up to 80 per cent of its bodyweight out of natural plastic. The plastic is extracted in fermentation vessels and dried to form granules. These can then be manufactured into biodegradable plastic packaging.

A shredder will accommodate an entire car. The Lindemann shredder (below right) compresses scrap before shearing it with 'hammers'. The pieces are hurled around the chamber until they become small fragments. They are then fed on to a conveyor belt.

Thyssen Henschel



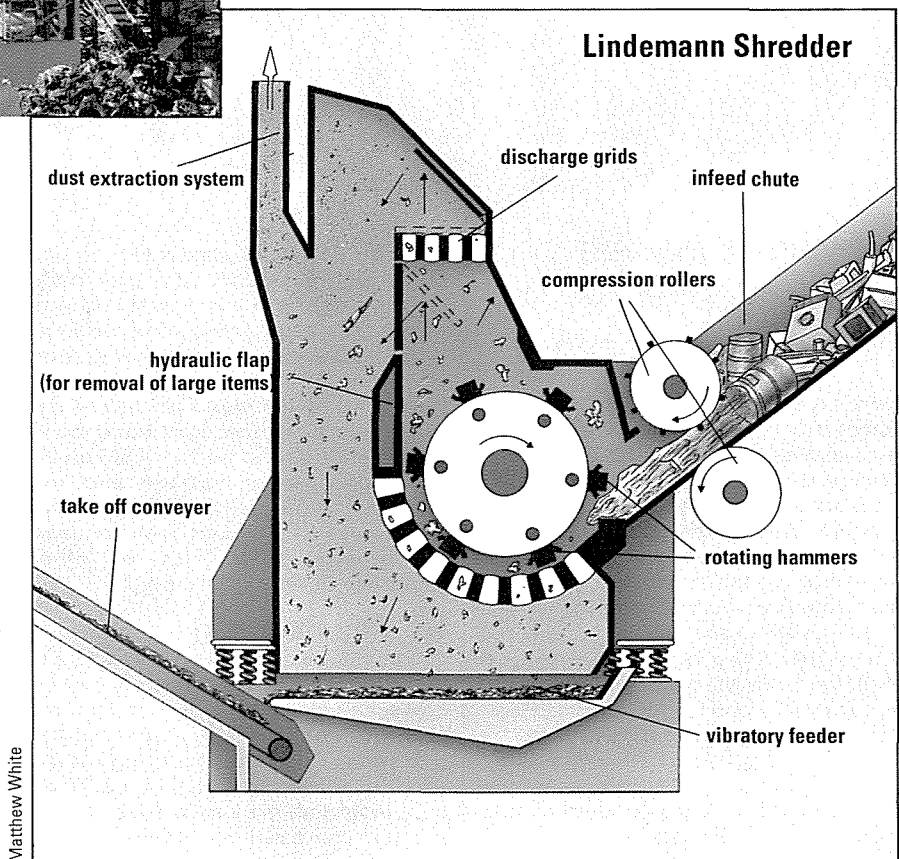
Many glass containers such as milk or soft drink bottles, can be reused without being remelted provided they are returned to the manufacturer undamaged. Glass makes up about ten per cent of household rubbish.

Bottle banks — places where people can deposit their waste bottles — have proved a useful source of glass. However, in Britain only eight per cent of glass is recycled, perhaps because there is only one bottle bank per 22,000 people. In Holland where considerably more glass is recycled, there is one bottle bank per 1400 people.

Soil conditioner

The recycling process is simple — old broken glass is added to new molten glass in a furnace. The result is high quality glass produced with a considerable saving in energy.

Alternatively, molten waste glass can be cooled in water to form a fine glass called frit. This is used as a soil conditioner or together with asphalt to surface roads. Frit can



Matthew White



RECYCLING

A landfill site, where some rubbish will decompose. Plastics, metals and glass, however, remain intact for decades. Using recycled glass (below), reduces waste and saves energy.

-  WASTE POWER
-  BIOPLASTIC
-  CAR SHREDDERS

Pascal Nieto/Jerrican
WE HUMAN BEINGS PRODUCE enormous quantities of waste – needlessly discarding all kinds of potentially valuable material, from newsprint to old motor cars. However, at last many industries are slowly waking up to the value of recycling used materials.

Manufactured goods cost the consumer more than just money. It has become startlingly apparent in recent years that:

- the earth's natural resources of oil, gas and coal are being depleted
- the destruction of trees in the rain forests threatens wildlife and contributes to the 'greenhouse effect'
- the environment is dangerously

polluted by waste products

About 35 million cars are made each year – and each year millions of them end up on the scrap heap. A huge amount of scrap metal can be recovered from cars and many of the parts can be salvaged for use in the same state. When cars have been stripped of useful parts, they can be fed into a steel furnace and the resultant steel sold off. A process developed in Belgium can be used to separate steel from the other materials in scrapped cars.

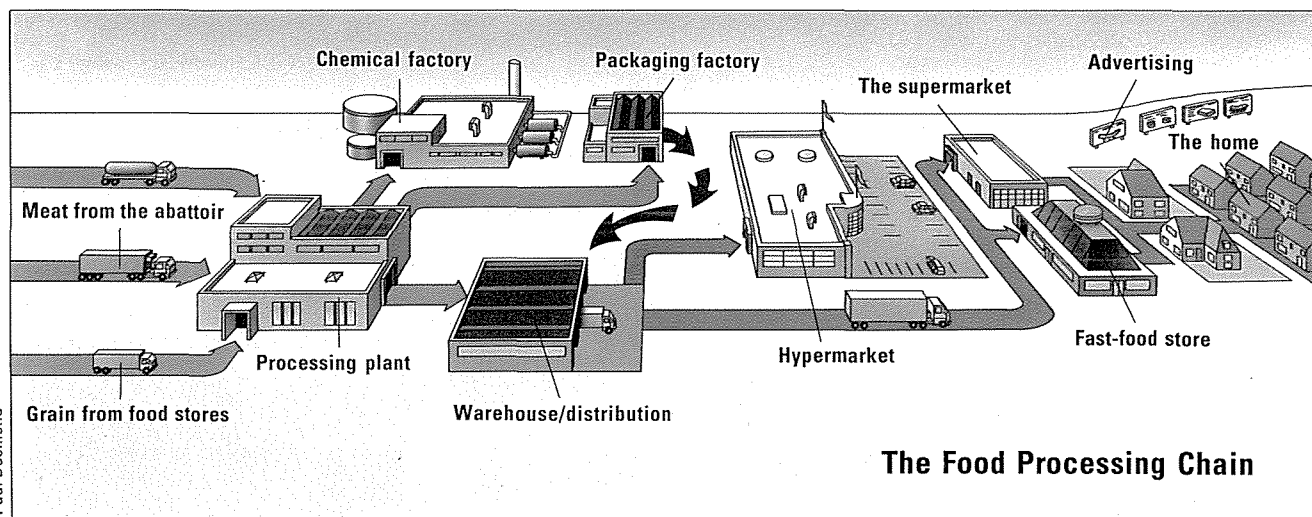
Reusing lead

Cold liquid nitrogen at nearly -200°C is sprayed on to the car body before it reaches the shredder. At this temperature the steel becomes brittle and breaks up into small fragments, leaving the other metals such as copper and aluminium as much larger pieces. The steel can then be easily melted down and reused.



United Glass Ltd





cookers, the sugar solutions are prevented from crystallizing (becoming solid) on cooling by the addition of corn syrup.

Mechanical kneading

When the mix is allowed to cool it is mechanically kneaded with flavourings and colourants, although in continuous production these ingredients may be added to the hot liquid syrup. The gooey mass is then shaped by being passed through rollers with impressions on them to create the eventual shape of the sweet. The final satin-like finish is achieved by repeatedly pulling and stretching the sticky mass using mechanical rotating arms.

Chocolate

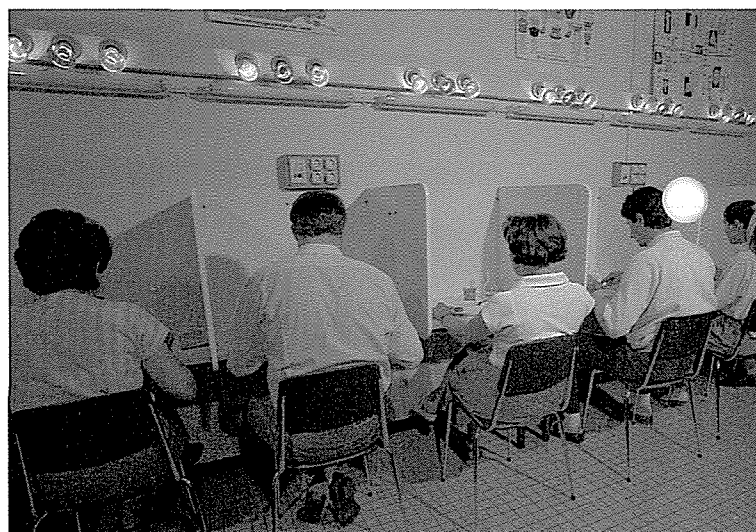
Chocolate confectionery falls mainly into two categories. Bars of solid chocolate are produced by pouring liquid chocolate into moulds, often fruit or nuts are added before the chocolate cools and sets.

Chocolate-covered products are made either by pouring the filling into a moulded chocolate shell, and then finishing this off with a layer of base chocolate, or by a process

known as enrobing.

A machine called an enrober, using a system of pumps and troughs, produces a curtain of chocolate through which the fillings are transported on a wire-mesh conveyor belt. Excess chocolate drains off through the mesh and is recycled. The coating is set by passing the chocolates through a cool air tunnel before packaging.

Professional tasters test a new product under artificially coloured lighting to ensure that the appearance of the food does not influence their judgement of its taste and texture.



Labat/Jerrican

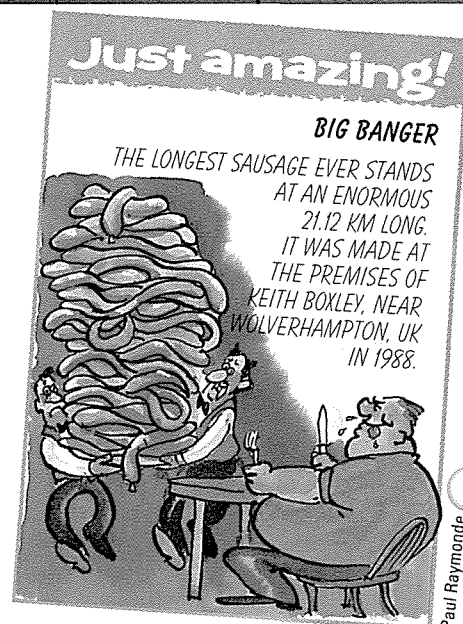
FRESH FROM THE LAB



ZEFA

Carrots are processed by food factories throughout the year, but one of the problems in the past has been their loss of sweetness and deterioration if overwintered in the field. Carrots kept in conventional storage facilities – immersed in a refrigerated liquid such as brine (very salty water) at 2°C – show root growth and become soft after four to five months.

However, new storage techniques are being developed by British scientists. In trials, where carrots have been kept at 5 °C, on banks of ice, at high humidity (moisture), they have shown negligible root growth and remained firm and crisp even after nine months storage. The new storage technique could help bridge the spring gap before the new season's crop.



Paul Raymond

cooled to, and remains at, 5°C to stop further bacterial growth. Pieces of fruit and various artificial or natural flavourings may be added at this last stage.

Blue cheese is another product to which starters are added during processing. Fungal cultures, sprinkled on to the cheese during an early stage of processing, produce the distinctive blue veins.

Factory cheeses

Traditionally a handmade craft, cheesemaking has adapted well to mechanization. French Roquefort, for instance, a blue cheese, can be produced and stored in the factory and still taste like its traditional counterpart which was matured in caves.

Milk coating

Scientists are currently investigating different ways of keeping food fresh in its natural state – without, for instance, freezing or drying it. With peeled or cut fruit or vegetables, one method is to coat the food with an edible film of milk or cereal proteins and ascorbic acid (vitamin C).

When applied to the cut side of an apple, for instance, the coating prevents oxygen in the air combining with the fruit enzymes and turning them brown. By keeping



Cadbury Ltd

Sweets pass through an enrober – under a curtain of chocolate liquid. Excess icing falls through the wire belt and is recycled.

moisture in and air out, the coating keeps fruit fresh for up to three days.

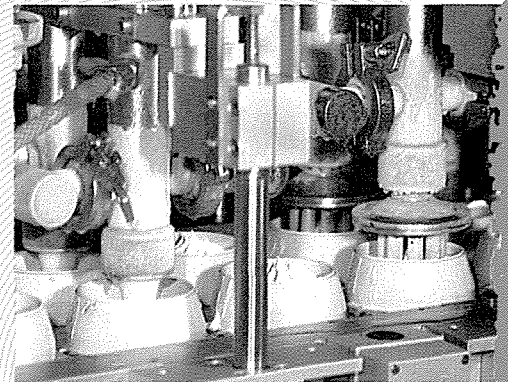
In future we may also be able to buy fresh salads in tins. A food chemist in New York had discovered an enzyme existing in most plant tissues that can reverse the softening effect that cooking has on vegetables. While cooking plays an important role in ridding vegetables

of bacteria before canning, these enzymes could help to keep them crisp and firm.

Boiling sugar

Sweets purchased from the local corner shop begin life as just a few ingredients at the start of a mass production process. Hard boiled sweets such as fruit drops, clear mints, butterscotch and barley sugar, start out as boiled solutions of sugars. Heated in steam pressure

TASTY EXTRACTS



Alfred & Co Ltd/Technogel

Today many countries are restricting the use of harmful food and drink additives. Cola drinks will fade to light brown as the caramel used to colour them is cut back by legislation. Red cheeses will become pale as titanium dioxide is restricted. Similarly, ice cream (above) will be much more pale.

Natural flavourings, aromas and colourings are difficult to extract from plants, fruits and vegetables and are vulnerable to climate and disease. But scientists have isolated the cells which produce these effects and have grown them in the laboratory. This means that in future, natural flavourings will be produced all year round and will replace artificial flavours used in, for instance, ice cream.

Many food factories still rely heavily on human labour. Canning (below) is one area that has been almost fully automated. Cans can now be filled and sealed at a rate of 2,000 per minute.



HJ Heinz Company Ltd

ZEFA

ture of 82°C for 10 minutes.

This kills salmonella and listeria bacteria, among others, which cannot survive above 72°C. The pots are manually checked during cooking with a needle probe digital thermometer to make sure the pâté is cooked right through.

The cooked pâté is packaged,

Quality control checks, for colour blemishes, are carried out before the potato crisps are automatically weighed and bagged.



Tony Stone Photo Library, London



Daudier/Jerrican

then cooled rapidly in liquid nitrogen to a temperature below which bacteria cannot grow. Small quantities of the product are checked in the laboratory for the presence of bacteria, and any contaminated batches are withdrawn.

The cold chain

A 'cold chain' ensures that the pâté reaches the customer in top condition — ie from the factory kitchen to refrigerated transport vans to refrigerated displays in shops and supermarkets the pâté is continually

ZEFA



Sausage meat is squeezed out in a continuous 'rope' from an automated machine before being portioned into individual links. Protective clothing to ensure good hygiene (far left) is essential in any factory producing food for human consumption.

Freezing food very fast to -196°C using liquid nitrogen coolant helps it retain its original shape and texture when thawed.

kept at a temperature below 5°C.

Temperature also plays a crucial part in the manufacture of stirred yogurt (yogurt which pours). First the level of solids in milk — the basic ingredient — is raised by evaporation, or by adding skimmed or concentrated milk. This is then homogenized — forced through tiny holes under pressure to break up the fat globules to a uniform size. This increases the viscosity (resistance to flow or stickiness) of the final product and gives it a smooth texture and creamy flavour.

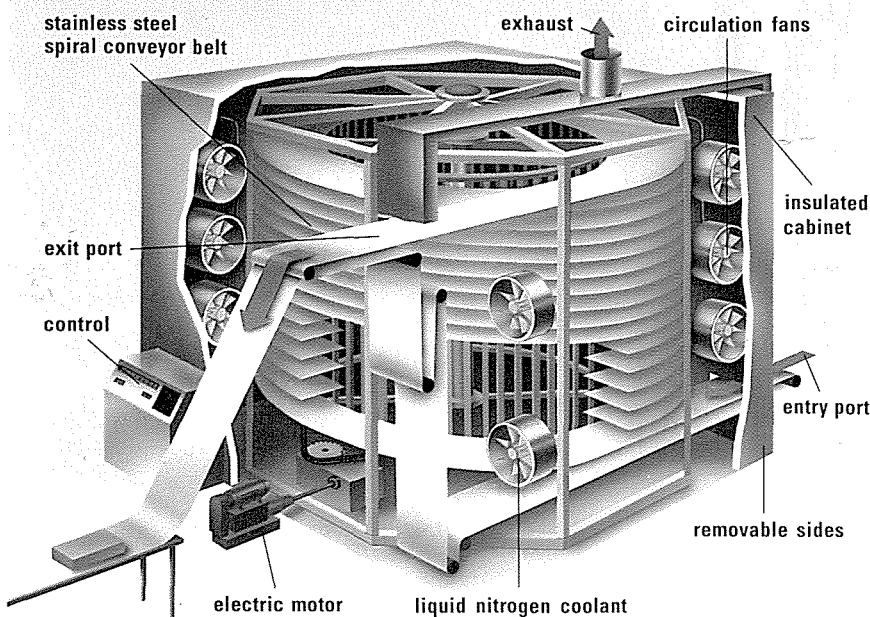
Pasteurization

The mixture is pasteurized at 85–95°C for 15–30 minutes to kill bacteria, then cooled to 40–45°C.

A culture of harmless bacteria called a 'starter' is added to the milk. The culture ferments the milk sugar (lactose) and turns the milk into yogurt. This process takes three to six hours. The culture, while growing, also produces an acid which gives yogurt its characteristic flavour.

Flavourings

Yogurt thickens during incubation as the milk proteins coagulate (set). After incubation the yogurt is



Liquid Nitrogen Freezing System

Matthew White

Q HEAT TREATMENT

Q NATURAL FLAVOURS

Q TINNED SALADS

FOOD INDUSTRY

EVERY WEEK, NEW FOODS find their way on to supermarket shelves, enticing us to try something different. This revolution in choice is partly due to innovations within the food processing industry, and partly to public demand for nutritious, time-saving meals.

Top manufacturers take great care to ensure that foods are safe for human consumption when they go on sale. The production of a new pâté product, for example, which by its nature is susceptible to contamination by micro-organisms, will be strictly controlled.

Chicken livers are first hand-washed under high intensity lights by staff wearing clean hats, boots

The food industry is becoming increasingly automated. A large bottling plant (above) can fill and seal 180,000 litre bottles of soft drink per hour.

and overalls, who have sterilized their hands in alcohol solution. These staff are tested to make sure they are not colour-blind so that they can detect any discolouration in the livers, along with the presence of stones or feathers.

The washed livers are processed

into a fine emulsion in stainless steel bowls by the action of rotary blades. Other ingredients such as bacon, sherry or other flavouring agents are added at this stage.

The flavoured mixture is injected into plastic pots that are loaded on to trays for cooking at a tempera-



Spectrum Colour Library

ZEFA

away from it below. To maintain a higher orbit, an object would have to travel more slowly, since gravity weakens with increasing distance. The Moon, for instance, needs a speed of only 3,500 km/h to stay circling around the Earth 380,000 kilometres away.

Just as the Shuttle falls continually while in orbit, everything inside the shuttle is in 'free-fall' as well. This is why astronauts feel weightless. It is not that gravity has disappeared, but that the astronauts are tumbling at exactly the same rate as their spaceship. For the same reason, a free-fall parachutist experiences a few, thrilling moments of weightlessness before he pulls his rip-cord.

Action and reaction

While gathering speed, the Shuttle demonstrates the third of Newton's laws of motion. This is that 'action and reaction are equal and opposite'. In other words, every force gives rise to an opposing force of the same strength. This is the principle by which rocket engines work.

When rocket fuel ignites, it turns into a hot gas that rushes out in all directions. Most of the gas slams against the wall of the combustion chamber in which the fuel is burnt.

At the rear of the chamber, though, is an exhaust nozzle through which some of the hot, fast-moving gas escapes. The force of this exhaust sets up an equal and opposite reaction force that drives the rocket.

Unfortunately, carrying more fuel adds to the total mass of a spacecraft. This extra mass makes it harder to alter course or speed. For this reason, mission planners, when sending robot probes to other planets, have sometimes resorted to a more ingenious method, called

the 'gravitational slingshot'.

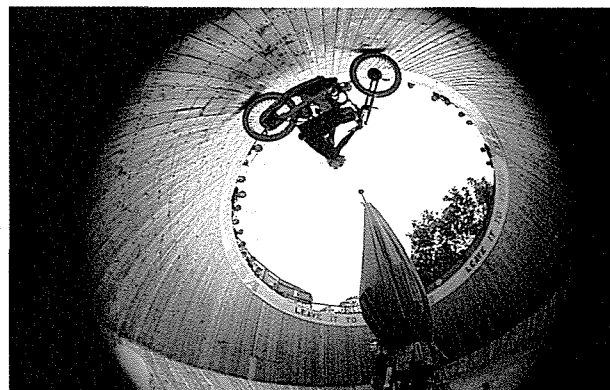
In the late 1970s, all four of the giant outer planets of the solar system — Jupiter, Saturn, Uranus, and Neptune — were lined up in such a way that a spacecraft could use the gravitational pull of each of these worlds to speed it up and swing it on course for the next encounter. In August 1989, after a journey of 12 years, the American Voyager 2 probe completed its four-planet mission when it skimmed just 4,900 kilometres above Neptune.

The Space Shuttle's three engines supply a thrust of 510,300 kg to escape the pull of Earth's gravity.



RAF Institute of Aviation Medicine

A human centrifuge multiplies gravity, or G, forces. Stationary, (above), a force of 1G operates. At 5G the soft facial tissues distort (left).



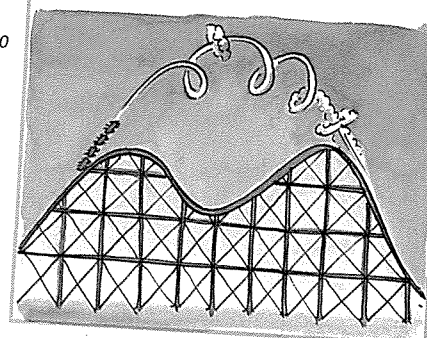
Topham Picture Library

A motorcyclist rides the wall of death. In this rare fairground attraction the rider can cheat gravity with centrifugal force. Riding up a ramp at speed he steers on to the wall, then rides around it, as near to the top edge as possible.

Just amazing!

THE VOMIT COMET

DROPPING 68.55 METRES AT A SPEED OF 128 KM/H THE 'STEEL PHANTOM' IN WEST MIFFLIN, PENNSYLVANIA, USA, IS THE FASTEST ROLLER-COASTER IN THE WORLD.

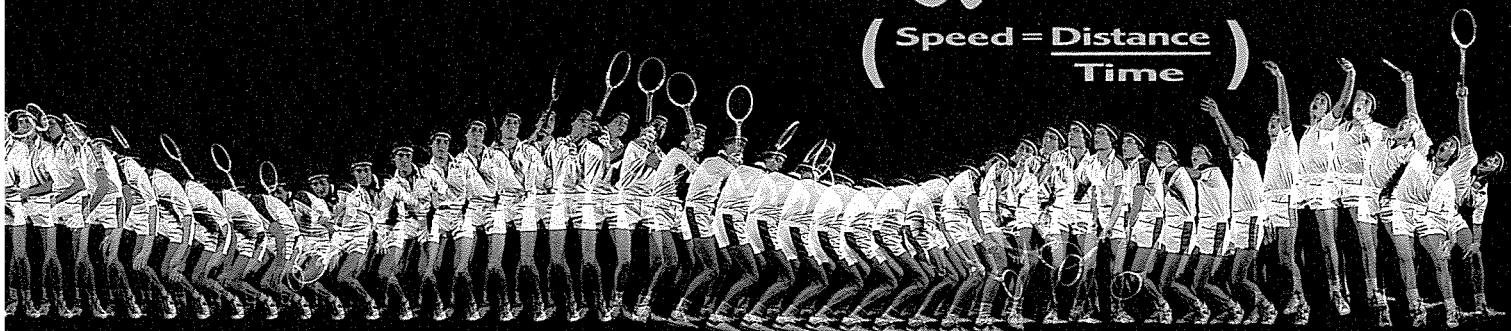


Paul Raymond

NASA/Science Photo Library

THE SPEED EQUATION

$$\left(\text{Speed} = \frac{\text{Distance}}{\text{Time}} \right)$$



EVERYTHING THAT MOVES, from a galaxy of a hundred billion stars to the tiniest speck of dust, obeys three simple, natural laws – Newton's laws of motion.

These laws are named after the great scientist Sir Isaac Newton, who discovered them. Newton's first law of motion says that an object will remain at rest or move at a steady speed in a straight line *unless* an outside force acts on it. For example, a ball thrown by an astronaut far out in Space would carry on moving forever at a constant speed. This is provided that it did not collide with anything or come under the influence of the gravity of a planet or star.

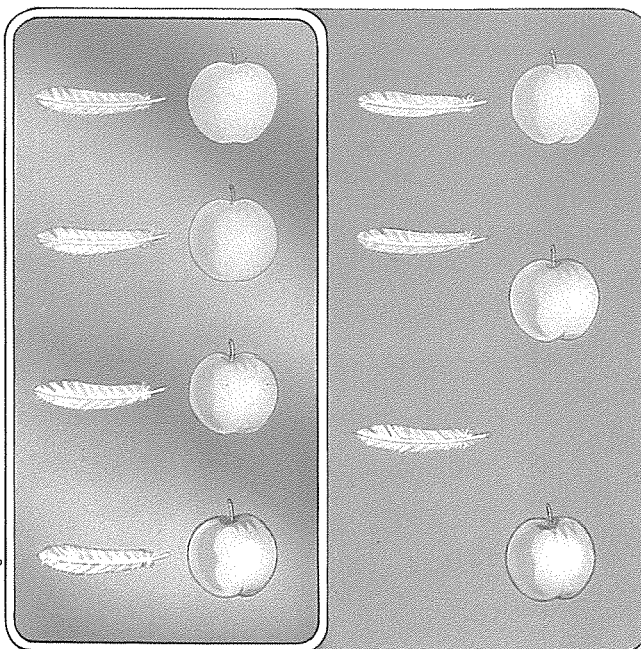
When forces are present, Newton's second law comes into play. According to this, the rate at which an object's speed changes depends on the strength of the force. So, for instance, the harder you pedal a bicycle the faster you will go. The bike's acceleration – its rate of increase of speed – depends on the strength of your effort.

● Opposing forces

To complicate matters, however, several forces are usually involved in any given situation. In the case of a bicycle, some of the force you apply to the pedals goes into fighting friction between the tyres and the road.

One of the greatest battles between forces takes place when the Space Shuttle blasts off from its launchpad. The orbiter and its cargo, weighing about 100 tonnes, has to reach a speed of over 28,000 km/h in order to go into orbit roughly 200 kilometres above the surface of the Earth.

At take-off, the complete Shuttle



John Houghton

system weighs 2,000 tonnes, consisting mostly of fuel. Its engines fire with the strength of three Concorde, gulping down 3 tonnes of fuel every second. On average, during its ascent, the Shuttle gathers speed at the astonishing rate of nearly 60 km/h each second! After just 8 minutes it reaches its targeted orbital height and speed. The titanic struggle against gravity has been won.

Yet gravity still continues to pull on the Shuttle as it circles around the Earth. So why does the spacecraft not simply fall back down as soon as its engines stop firing? The answer is that the Shuttle is falling, all the time, while it is in orbit! But the rate at which it falls is exactly matched by the rate at which the Earth's surface curves

The forces acting on a tennis ball are the result of the movements in the serving stroke.

ZEFA

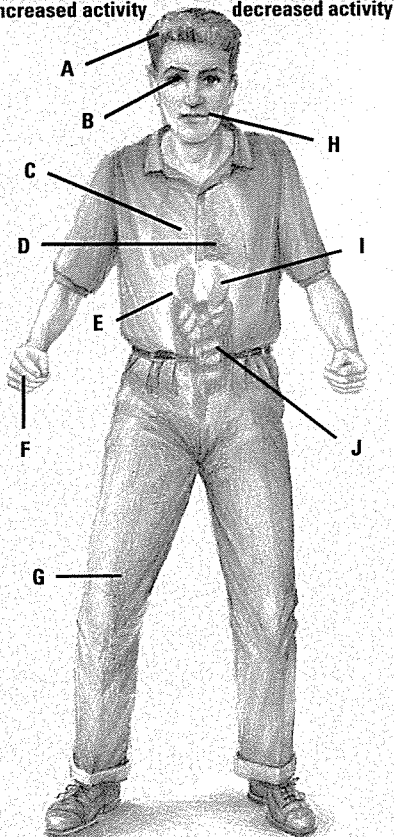
Gravity is a familiar force. In a vacuum (far left) a feather and an apple fall at exactly the same rate. Under normal conditions, though, (left) air resistance slows the feather. In the absence of gravity (below) astronauts experience weightlessness.



NASA

FIGHT OR FLIGHT

increased activity decreased activity



Alison Catley

When the body is under stress, the hormones adrenalin and, to a lesser extent, cortisol, are released into the blood stream. Hormones control many of the body's activities, including its preparations for fright, fight or flight.

A Hair prickles upwards to increase the sense of touch

B Eye pupils dilate to give clearer sight

C Breathing speeds up to take in more oxygen

D The heart pumps faster so that more blood can reach the muscles

E The liver releases glucose to fuel the muscles

F Skin sweats to prevent the body overheating and turns pale because blood is diverted to the muscles

G Muscles tense and give off lactic acid, which heightens anxiety

H The salivary glands dry up

I Blood vessels in the kidneys constrict

J Digestion slows down.

enjoyable and prevents it becoming boring. Some people, such as stuntmen or racing drivers, seem to become 'addicted' to the sudden surge of adrenalin extreme stress can bring. Only when taking a bend at 180 km an hour do they feel truly 'alive'.

Red alert

This 'fright, fight or flight' response is triggered every time you come up against a situation that makes you anxious or worried. The whole body is ready for action. But physical action is not usually required to deal with a long-running stressful situation. So the body remains tense and stressed.

Blood vessels stay constricted and high blood pressure becomes permanent. Ulcers may develop because the digestive system is not working properly. Neither is the immune system, so that colds, 'flu and all kinds of infections are

attack or stroke — together, the number one killers in industrialized countries.

Anxiety can be treated with drugs called tranquillizers. Librium, Valium and Mogadon are taken by millions of stress-sufferers. They calm the mind (some find they depress rather than soothe), relax muscles and control insomnia. However, tranquillizer-users find that the effectiveness is often short lived. There is also a



Gamma/Frank Spooner Pictures

Death-defying feats of a trapeze act and the monotony of working on an assembly line putting together microwaves have one thing in common — they are both stressful activities.



International Stock Exchange Photo Library

caught more easily. Sufferers complain of feeling 'on edge' and 'wound up' all the time. The body cannot keep this up forever. Exhaustion sets in and eventually there is usually some kind of mental or physical breakdown or both, as the two are closely linked.

Breakdown

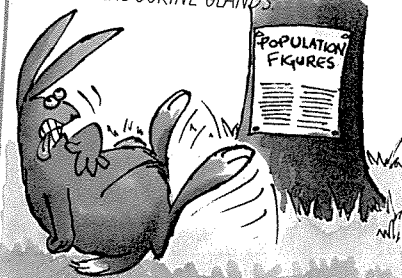
The sufferer becomes confused, angry and depressed, spiralling down to the point when he or she cannot cope, for the moment, with every day living. Under these circumstances, middle-aged people are particularly vulnerable to heart

danger that users might become addicted. When they stop taking the pills, they may get withdrawal symptoms, such as panic attacks and insomnia, which are worse than the original stress.

Just amazing!

DEATH WISH

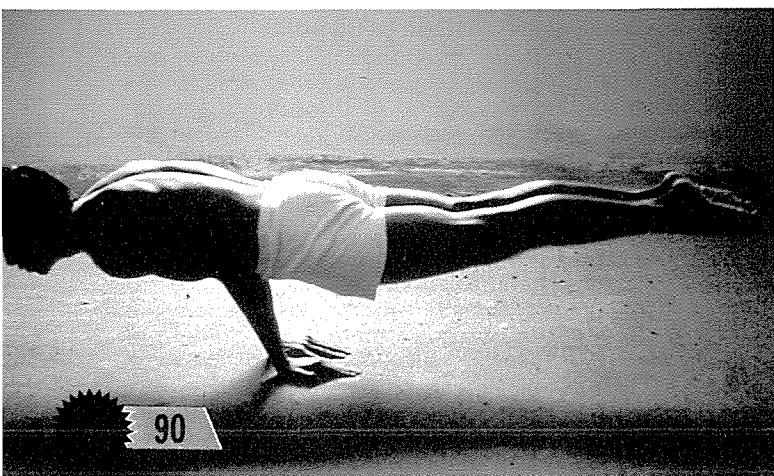
IN 1939, THE HARE POPULATION OF THE AMERICAN STATE OF MINNESOTA PLUMMETED. STRESS CAUSED BY OVERCROWDING TRIGGERED 'SHOCK DISEASE' — A FATAL OVER-PRODUCTION OF THE ENDOCRINE GLANDS



Paul Raymonde

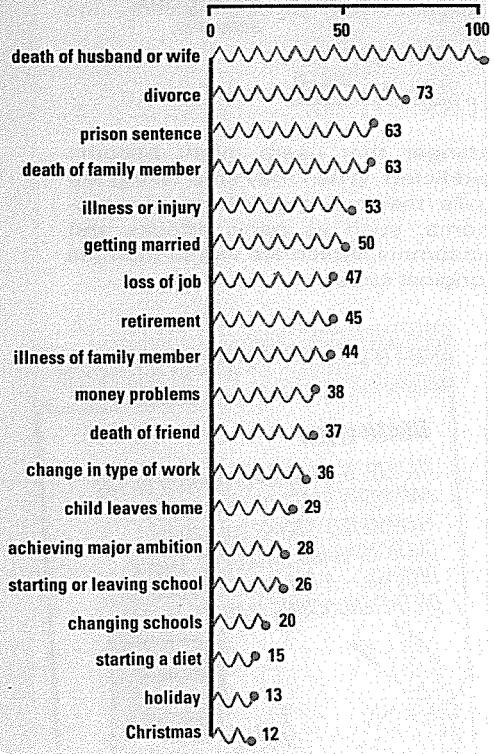
Yoga is an effective antidote to stress. Hatha yoga is a series of physical exercises designed to benefit most of the muscles, organs and glands, and make both mind and body feel alert and relaxed.

Rex Features





Death dogs every step for soldiers engaged in jungle warfare. The stress was so great for men fighting in the Vietnam war, as shown in the film Platoon, that many suffered mental breakdowns.



STRESS THE KILLER

Orion/Kobal Collection

-  THE PAIN GATE
-  CONTROLLING STRESS
-  TRANQUILLIZERS

TOO MUCH STRESS CAN BE fatal. Stress-induced disorders have replaced infectious diseases as the major medical problem in industrialized countries. But stress is also a life-saver — one of the basic ingredients of the survival instinct.

You feel stress — fear or anxiety — when confronted with a situation outside your control. This can be a single event or a long-term problem. Stress factors, as they are called, vary from a man holding a gun to your head to having to work every day with someone you dislike. All

change is stressful — even birthdays and Christmas!

Faced with danger, the brain goes into red alert and prepares the body to run away or stand and fight. This is called the 'fright, fight or flight' response. Muscles tense, ready to move in an instant, the heart races and breathing quickens.

Under pressure

When the body is under extreme stress, chemicals called endorphins are released in the brain that suppress feelings of pain. This is the 'pain gate' phenomenon. For example, a fireman or soldier who is burned or injured, often does not realize the extent of his injuries until the danger has passed and his mind begins to calm down.

There is another side to stress — it can be good for you. An element of stress makes some kinds of work

Stress affects people in different ways. Figures above are averages. If several stressful events, happening together, total over 160 points, a person's health may suffer.

Mark Franklin





Nuclear power workers, such as this maintenance engineer at the Sellafield plant in northern England, wear a totally enclosed suit and breathe a remote supply of oxygen.

Today/ReX Features

The flare from the high voltage electric arc would blind a welder were he not viewing the workpiece through a very dark lens incorporated into a protective steel face shield.



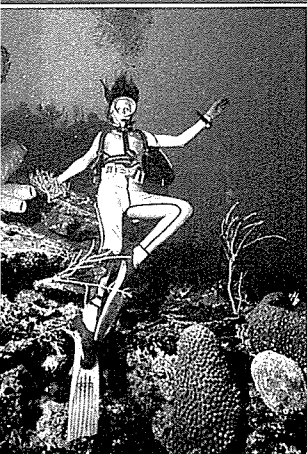
International Stock Exchange Photo Library



A de Meni/Science Photo Library

Asbestos, in spite of its dangers, is the only material capable of offering protection from the extremely high temperatures of chemical fires.

SCUBA divers normally use a neoprene wet-suit to keep warm. By retaining millions of tiny air bubbles, neoprene acts as an insulator, preventing the loss of natural body heat.

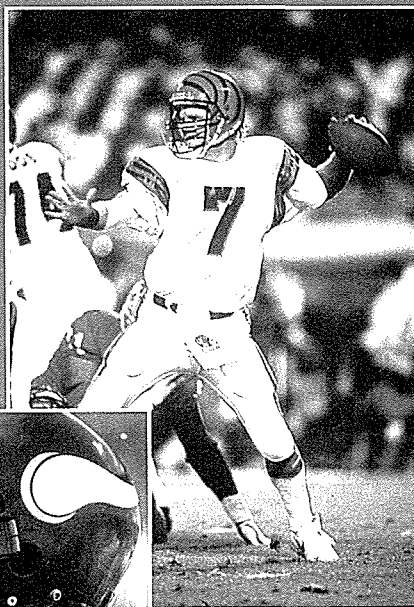


Mike Hewitt/Action-Plus

Steve Powell/Allsport



Insulation is the key to retaining warmth in the air for hang glider pilots. Often, a close-fitting quilt is worn over a heavily padded flying suit.



ReX Features

American football players face weights of 130 kg travelling at 35 km/h. Injury is avoided with body padding, crash helmets, face grilles, knee and elbow supports, shoulder, hip and thigh pads and boxing style gumshields.



Action-Plus

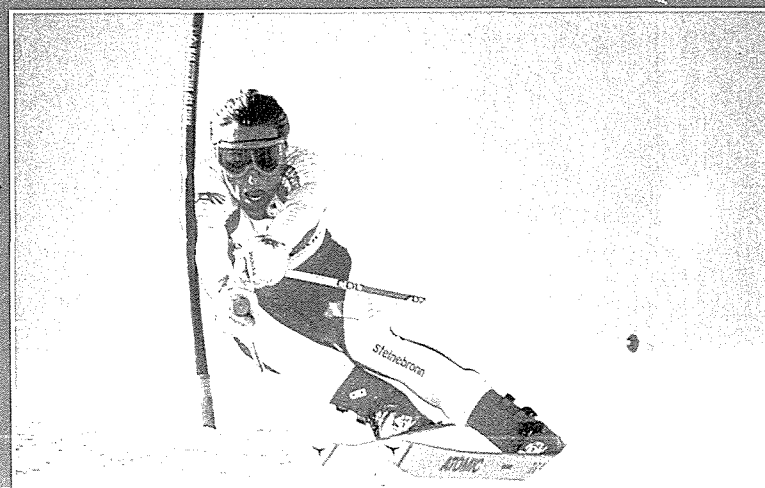
The extreme cold, of high altitude mountain climbing can be combated with many layers of clothing, firstly thermal and lastly wind and waterproof.

Action-Plus



Allsport/Vandystadt

Slalom skiers need a well-insulated suit that is a close-fit to reduce drag, yet not too tight to restrict movement. Their ski boots have sensors that cause them to release in a fall.

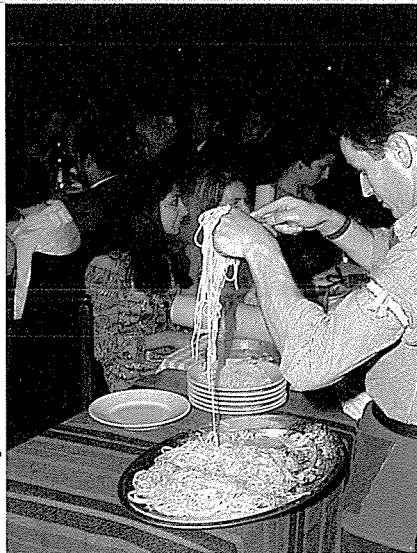


major joints lubricated, so that you can twist and turn and bend through a full range of movement. It maintains the strength of muscles and the efficiency of the heart and lungs.

● Oiling the machine

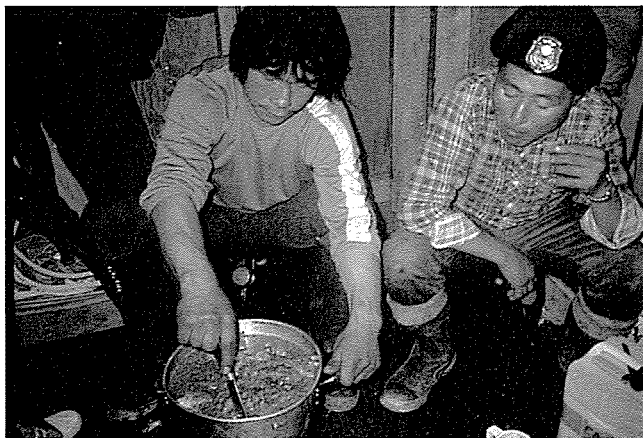
To keep the body in good physical condition does not need the dedication of an athlete – a few minutes a week devoted to a balanced exercise programme is sufficient. The typical posture of old age – hunched back, drooping head and round shoulders – caused by the joints stiffening up can be avoided by long-term regular exercise.

Robert Harding Picture Library



Pasta is made from flours, notably durum. It is a good source of complex carbohydrates and is fat-free.

Gamma/Frank Spooner Pictures



Eskimos living in the Arctic enjoy a diet based on meat and fish, eaten lightly boiled, raw or even frozen.

The body is designed so that, when it is upright, the weight is distributed evenly over the supporting bones with the strongest bones taking the greatest weight. A sagging posture upsets this balance and can not only cause backache, but also constricts the chest, lead-

ing to breathing and digestion problems, and places unnecessary strain on other muscles. One method of improving the way we stand, walk, sit and talk is called the Alexander principle, named after the originator of this technique, F Matthias Alexander. Instructors claim that the correct alignment of the head and

BODY MAINTENANCE

neck is crucial for the wellbeing of the whole body.

As well as exercise, the body needs rest. Deep relaxation is an essential counterbalance to everyday stress. People practising daily meditation have been monitored: during meditation each person's breathing slowed, the heart beat more slowly and (if he or she had high blood pressure) blood pressure dropped. Often, a bout of vigorous exercise brings on a feeling of complete relaxation afterwards.

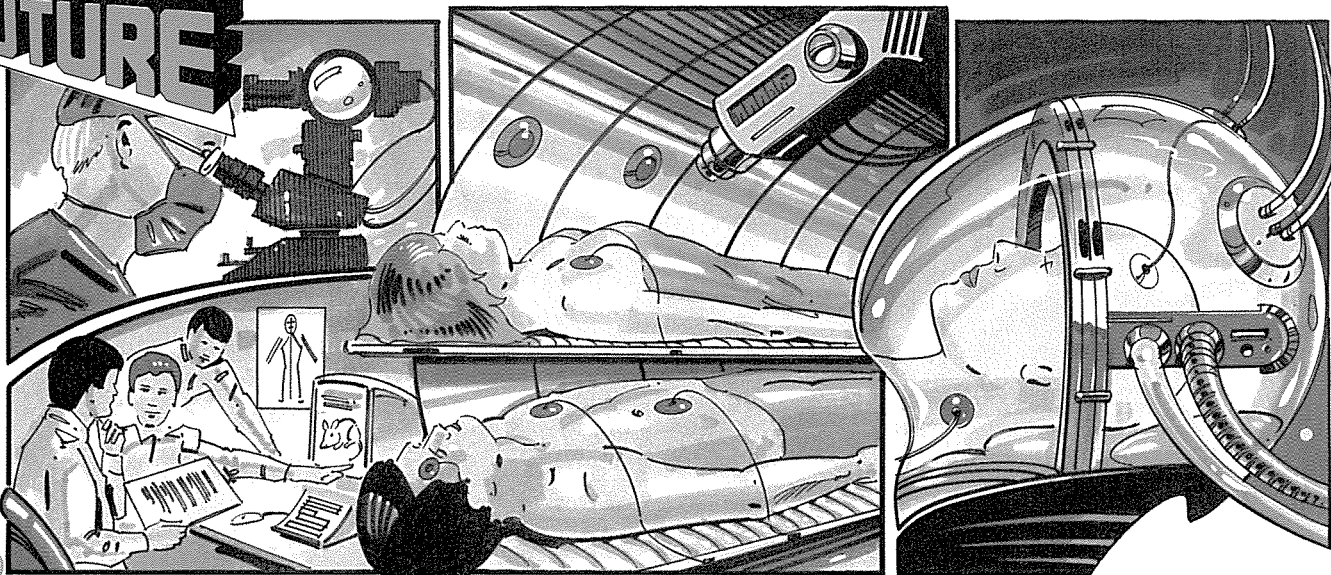
THE LONG-LIFE DIET

A low-calorie diet is the secret to long life, according to American gerontologist (old-age expert) Dr Roy Walford of the University of California. In his books, Dr Walford recommends a 1500-calorie-a-day diet, which is around half of what most adults eat. His theory is that a lean diet, made up of foods such as tofu (soya bean curd) and whole-wheat pasta, will not only help you live longer but provide far more vitality.

Sleep is rest in its purest form. During sleep, growth hormones are carried by the blood to tissues and organs of the body, stimulating them to repair themselves and to grow. Children obviously do more growing than adults (particularly of bone tissue) and this is why they need more sleep. A one-year-old child needs 14 hours sleep in contrast to the 8 hours required by the average adult. After this period of renewal, the body awakes, ready to face a new day.

INTO THE FUTURE

THE SECRET OF LONGEVITY



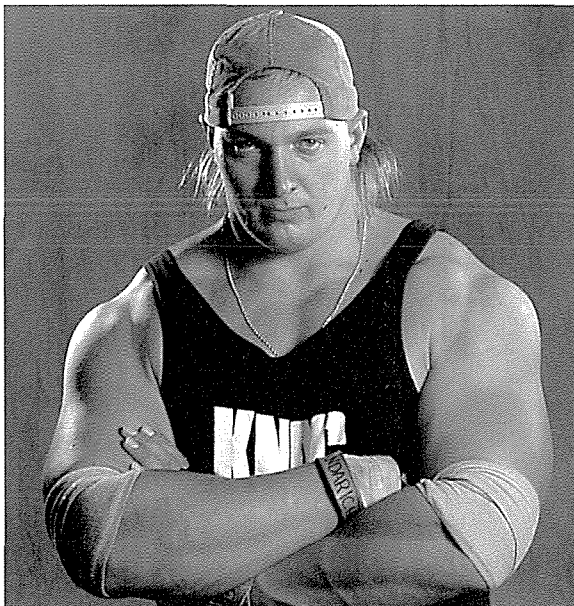
▲ American scientists have claimed that lowering body temperature slows down the ageing process – not only in mice, but in human beings too.

▲ Eventually, people may go to sleep in refrigerators, lowering their temperatures by several degrees – and so increase their lifespan to around 150 years.

▲ A special 'sleeping helmet', using low-power microwaves, will be worn to make the brain believe the body is warm. Thus the sleeper will not feel cold.

Joe Lawrence

Tony Mandarich, regarded as possibly the best ever offensive tackle in American football, eats and drinks over 15,000 calories every day – five times a man's normal intake. The amount Tony eats and drinks in just one week is listed on the right. He is 1.98 metres tall and weighs 143 kg. 'The incredible bulk' eats to maintain this weight while training four hours a day in a gym. He claims never to have taken anabolic steroids to build up muscle power.



You Magazine/Solo

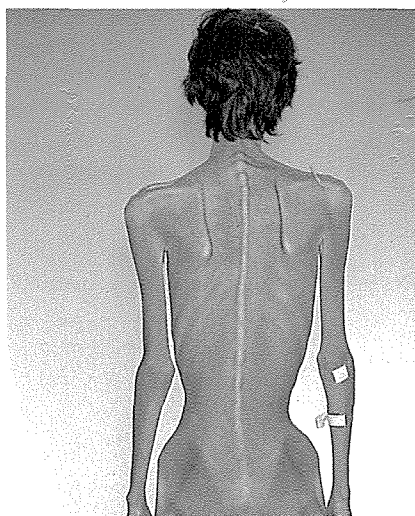
the amount of heat produced. A gram of protein or carbohydrate has 4.1 calories, whereas a gram of fat has 9.4 calories. So the body gains a lot more energy from 1 gram of fat than 1 gram of protein.

The amount of food, in terms of calories, that each individual needs to maintain a healthy body weight varies from person to person, partly depending on how much exercise that person takes. The average young man needs around 3,200 calories per day and the average woman 2,300 calories.

Balance

When more calories are taken in than burnt up, the body stores the excess as fat under the skin, around the muscles and around internal organs such as the heart and kidneys. If someone does not eat enough to balance the amount of energy he or she is expending, the body compensates by using up its stores of fat. If the calorie deficiency

Anorexia nervosa is known as the 'slimmer's disease'. Refusing to believe that they are seriously underweight, sufferers may be in danger of starving themselves to death.



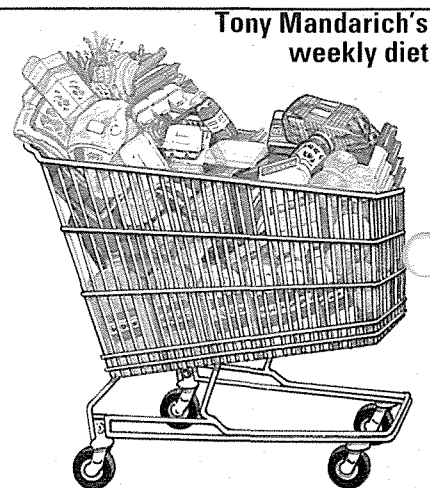
Charing Cross & Westminster Medical School

is extreme and the body's fat stores are exhausted, it begins to use protein as its source of energy. This protein is stored in muscles, so if the body has to use this, the muscles will lose their strength and waste away.

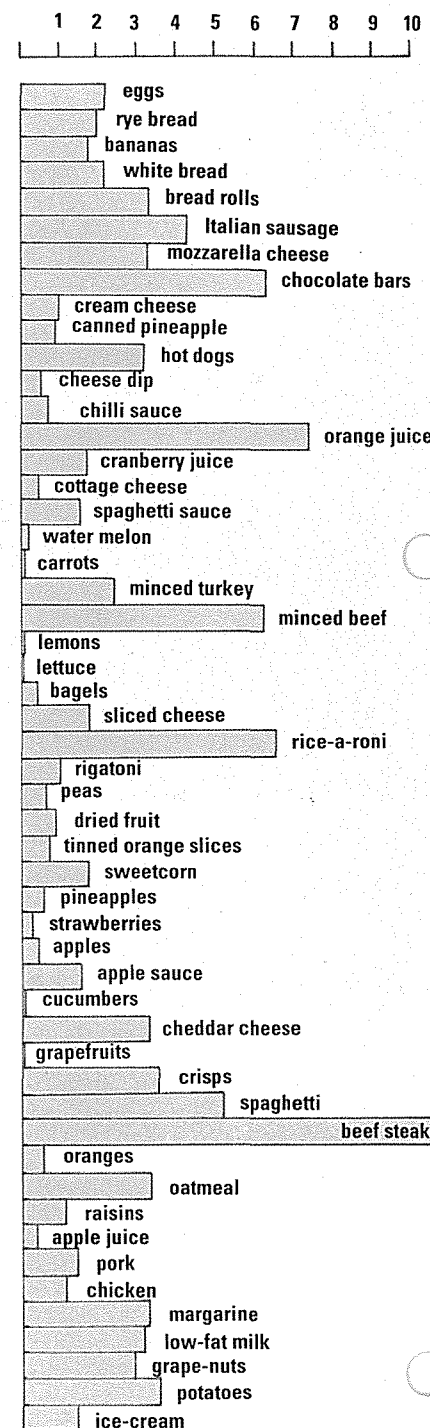
Exclusion diets

Many people are allergic to some foods, for example, dairy products or any food containing wheat. Typical symptoms are headaches, rashes or diarrhoea. To find out what the sufferer is allergic to, he may be advised to go on an exclusion diet. This includes only a few different foods – those least likely to cause an allergy. Then other foods are gradually reintroduced until the symptoms flare up again and the allergy has been pinpointed.

The body must be exercised regularly, like any other machine, or it will seize up. Exercise keeps the



thousands of Calories



number of Calories eaten in a week

by Tony Mandarich 108,000

by the average adult man 22,500

John Houghton

Just amazing!

A HEAVY DRINKER

TO LOSE WEIGHT, ANGUS BARBIERI WENT FOR 382 DAYS WITHOUT EATING SOLID FOOD. HE LIVED ON TEA, COFFEE, WATER AND VITAMINS. HE WENT FROM 214.1 TO 80.74 KG, LOSING 133.36 KG – THE COMBINED WEIGHT OF TWO LESSER MEN!



Paul Raymond



BODY MAINTENANCE

- Q WEIGHT CONTROL
- Q FUEL REQUIREMENTS
- Q RELAXATION

THE HUMAN BODY RUNS automatically, in spite of its complexity. Yet regular maintenance is absolutely vital if the machine is not to break down or grind to a halt.

The body needs the right kind and quantity of fuel, rest at regular intervals, and exercise to keep it running smoothly. The better you look after it, the better it works.

The body needs food to provide it with energy. This energy powers a huge variety of everyday functions. Even when we are asleep the body needs energy, to pump blood around the body, to maintain the body at a constant temperature and to digest food. During strenuous exercise, the body may burn up 20 times the amount of energy used when at rest. Food is also used as building materials to repair the body

and replace each one of its 75 million million cells.

Good health and weight control depends on a balanced diet, so that the right amount of energy is provided by the food consumed. There should also be the right balance between energy-rich foods such as carbohydrates and fats, and body-building and repair foods (proteins). A balanced meal contains around one part protein, one part fat, five parts carbohydrates and foods rich in minerals, vitamins and roughage.

Rough stuff

Roughage, or dietary fibre, is the part of unrefined cereals, fruits and vegetables that is not digested and passes almost unchanged through the digestive system. Roughage cleans out any food that may have lodged itself along the lining of the intestines. In this way, a high fibre diet helps prevent constipation and more serious disorders such as bowel cancer.

The energy value of food is measured in calories. One calorie is the amount of heat necessary to raise



Tony Stone Photo Library, London
Jean-Marc Barrey/Alisport

The dietary needs of a swimmer (main picture) and a sumo wrestler (inset) are quite different – high-protein foods for the swimmer to build up muscle and lots of carbohydrates and fats for the sumo wrestler for bulk.

the temperature of 1 gm of water by 1°C. Strictly, calories are units too tiny to apply to quantities of food and what we normally refer to as calories are really kilocalories – one thousand calories. The number of calories in a particular food can be calculated by burning a certain weight of that food and measuring

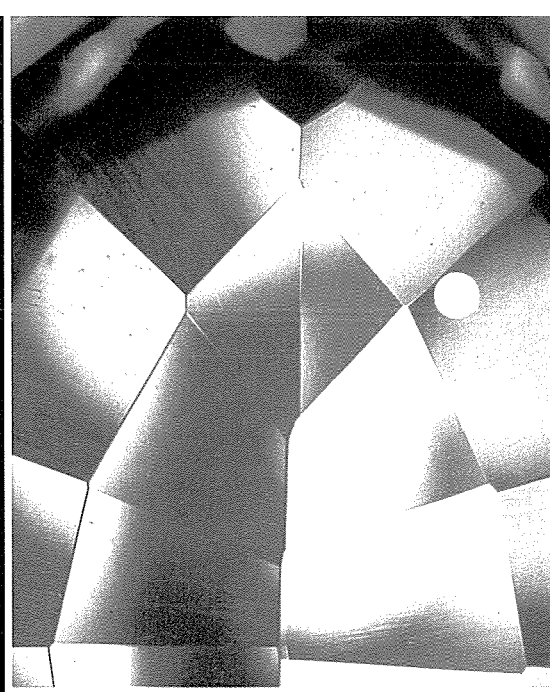


ZEFA

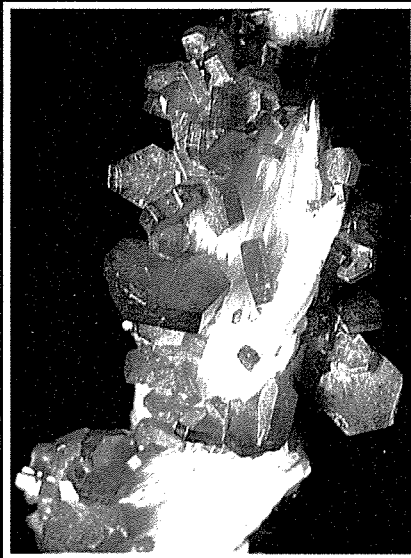
Sapphire is a crystal of aluminium oxide, or corundum, naturally tinted blue. When tinted red, the mineral is called ruby.

A gold nugget found in its pure state because the metal is unaffected by moisture, oxygen and corrosion by acids in the soil.

John Walsh/SPL



The hexagonal crystals of vanadinite, a mineral found in Morocco, are formed by the oxidation of lead minerals.



Arnold Fisher/SPL

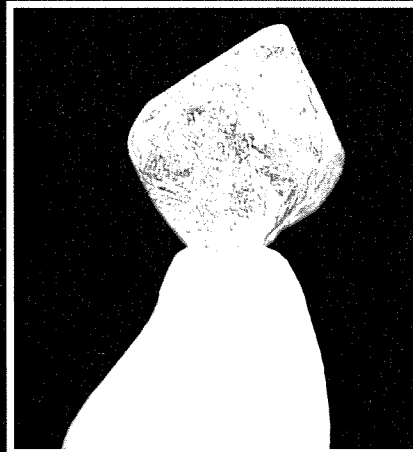
Crystals of aluminium – a metal that occurs commonly as traces worldwide and is also concentrated in some areas.

Arnold Fisher/SPL

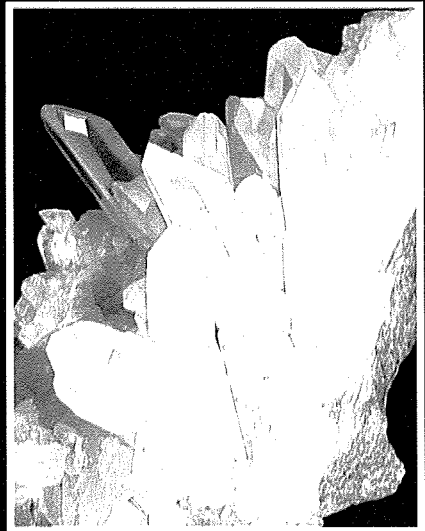


Crocoite is deposited when hot solutions of chromic acid react with various lead minerals.

Uncut diamonds bear no relation to the sparkling gems that have been cut and polished to reflect light.



Arnold Fisher/SPL

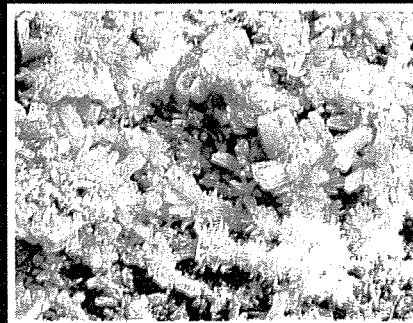


Sinclair Stammers/SPL

Pure silver is found in large quantities in the Cobalt District of Ontario and in Russia and Mexico.

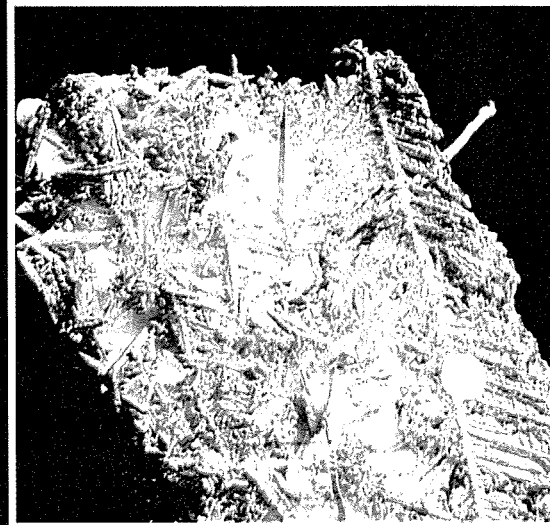
Tony Stone Photo Library, London

Crystals of pyromorphite, a mineral formed by the action of water containing phosphoric acid on other lead minerals.



Arnold Fisher/SPL

Geoscience Features Picture Library



cast, or open-pit, mining. It is basically a large-scale quarrying site, with huge bucket-wheel excavators on crawler tracks and other heavy vehicles digging and moving rock. Minerals such as aluminium, copper and iron are extracted by open-cast mining.

Big strippers

Strip mining is another form of open-cast mining in which the rock is drilled and blasted to loosen the material. It is then stripped or scraped out by giant drag lines, shovels or excavators.

Open-cast mining is very destructive of the environment. Sometimes when the mine is worked out, the waste rock and soil are replaced

and the area is landscaped, but the disruption to plant and animal life takes many years to put right.

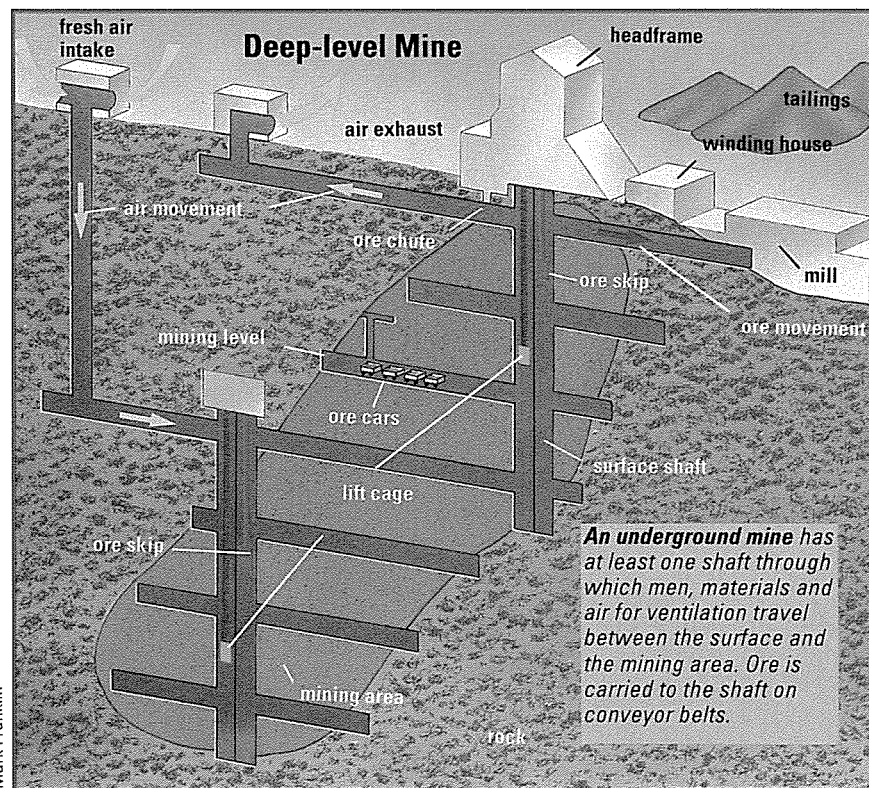
However, open-cast mining is cheaper than underground mining because much larger equipment can be used. So it is used wherever there are valuable minerals. About 70 per cent of ores come from surface mining where equipment can dig down to 500 metres.

To make deep mining worthwhile, the yield must be high or the product rare and expensive, like diamonds. Shafts, tunnels, lighting,

Fortune hunters laden with soil they hope contains a golden nugget scramble up ladders in a Brazilian mine.



Gamma/Frank Spooner Pictures



Mark Franklin

number of rock faces exposed and the lines of weakness in the rock.

In large mines, electrical or battery-operated rail systems haul hundreds of tonnes of coal or ore into the main shaft. Conveyor belt systems are also common in coal mines. For continuous mining, some mines employ a track-mounted unit with teeth on rotating chains as the cutting head.

Once the cutting head has bored into the bottom of the rock face, it is gradually raised by hydraulic jacks to the top of the seam so it cuts out the material as it moves upwards. The chopped up material passes back over the teeth and chains on to a conveyor belt.

MINING DISASTER



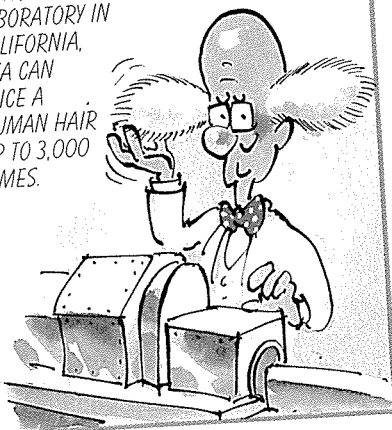
Rex Features Ltd

The hazards of mining were brought home to residents in the Brazilian town of Marabá in 1986 when a disaster in the Serra Pelada mine, one of the world's most important open gold mines, claimed the lives of 50 people. The victims were engulfed by a mud slide, brought about by weeks of near-continuous heavy rain, as they dug and sifted ton after ton of earth in the hope of finding nuggets of gold in its uncombined, pure state.

Just amazing!

CUT TO SHREDS

A DIAMOND-TURNING MACHINE AT THE LAWRENCE LIVERMORE LABORATORY IN CALIFORNIA, USA CAN SLICE A HUMAN HAIR UP TO 3,000 TIMES.



Paul Raymond

ventilation and water pumps are all expensive requirements for deep mining. Deep mines are usually excavated to a depth of about 1,830 metres, although some diamond mines may be as deep as 3,050 metres.

Once the shaft has been dug, timber, steel and concrete pillars are used to support the rock and protect the workers. The ore or rock must be drilled or blasted to produce manageable-sized rock, which is carried to the surface by hoists on the main shaft. The drilling is usually done by pneumatic hammers.

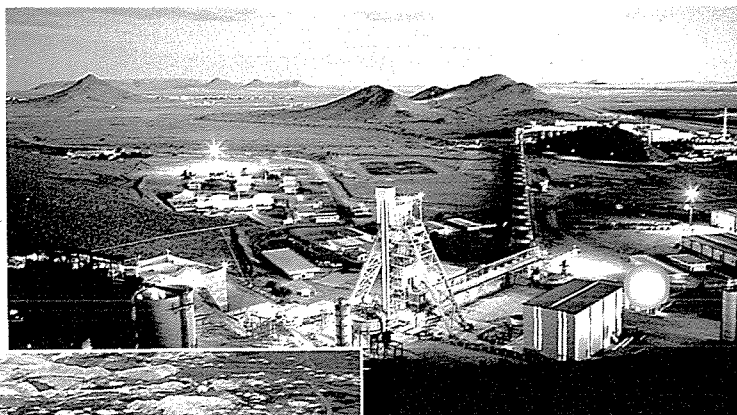
Explosive power

Blasting is sometimes used to free ore in underground mines. Holes drilled into the rock are filled with small explosive charges, which are set off to break up the rock. The location and angle of drill holes is determined by the type of rock, the

the bottom of this 3777-metre mine reach 55°C.

Diamond is the hardest substance known. It is a form of carbon — like soot or graphite — transformed by great heat and extremely high pressures deep within the Earth's crust. The top four diamond producing countries are Australia, Zaire, Botswana and the USSR.

The Black Mountain metal mine in Africa where ore is mined underground and hoisted in ore skips to the surface. The ore is then conveyed to a mill and ground before shipment.



Mining for opals in Australia has left a scar on the landscape which will take many years to put right. Australian white and black opals are world-famous as gemstones.

Consolidated Gold Fields

Shock waves

To find minerals, prospectors set off underground explosions which send seismic waves, or shocks, through the rocks and soil. The waves pass through different materials at different speeds and are deflected by the material.

These echoes are picked up by microphones on the surface and analysed to build up a picture of the types of rock, soil and minerals in that area. Only if this type of survey

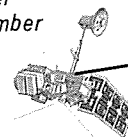
Australian Overseas Information Service, London

A bucket-wheel excavator scoops up sand and moves it along conveyors to expose ore containing diamonds.

Locating oil is a kind of detective work involving piecing together data from a number of tests and surveys.

indicates that minerals are present will engineers begin work.

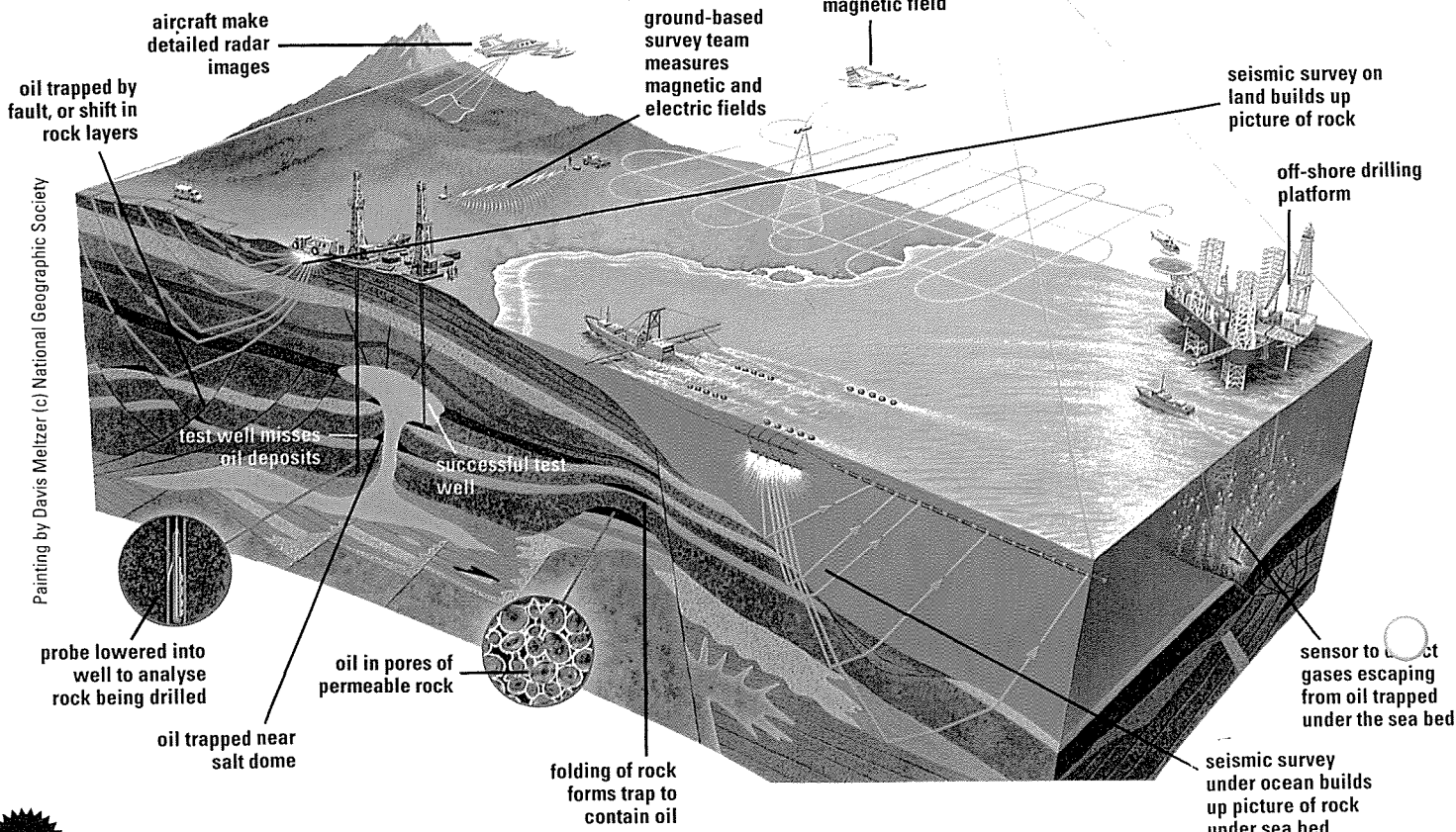
The way in which minerals, including coal and most metals, are removed from the ground depends on the size, shape and location of the deposit. When minerals lie close to the Earth's surface, the vegetation and top layers of soil, sand and rock (known as the overburden) are removed so the ore can be dug out. This method is known as open-



satellite photographs large areas of land and oceans

aircraft towing sensor to measure magnetic field

Searching for Oil



Painting by Davis Meltzer (c) National Geographic Society

MINING THE EARTH

De Beers Consolidated Mines Ltd

Miners drilling a diamond-bearing rock face deep underground. They break the rock into manageable sizes that can be lifted to the surface.

Mining machines come in all shapes and sizes. This electric drill has a left and a right drill arm so it can work on either side of a rock without having to turn around.

When the pressure subsides, the oil has to be pumped out.

Iron makes up about 5 per cent of the Earth's crust and is mined in large quantities to provide about 1000 million tonnes each year. Aluminium ore, known as bauxite, and copper ores are also heavily mined for industrial use.

Copper is becoming scarce and mining companies have literally moved mountains to win it. For example, in the village of Bougainville in the Solomon Islands, villagers were forced from their land and the jungle cover eradicated along with 40 million tonnes of surface material above the copper ore. But political disturbances led to the closure of the mine in 1989.

King of metals

Gold, the highly prized yellow metal, is found in grains, flakes and nuggets, but is scarce. To satisfy the demand for this metal, men work in deep mines, kilometres beneath the surface, in hot, wet and dangerous conditions. The same sites that contain gold may also contain uranium — a radioactive metal used in nuclear power plants.

Gold is extracted from the world's deepest mine at Carletonville in South Africa. Temperatures at

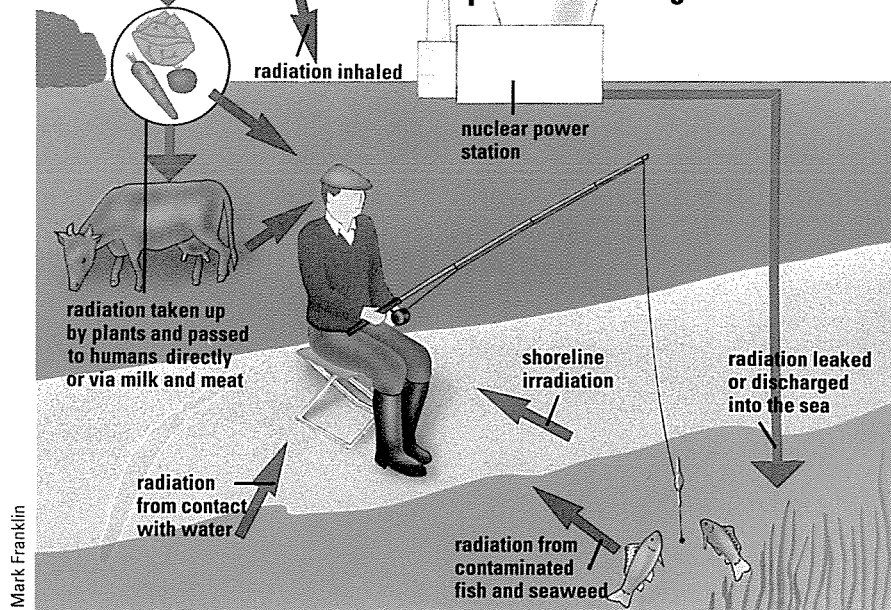
THE EARTH IS A HUGE BALL OF energy and minerals, which provide us with everything — from fuel for warmth to metals and plastics for industry.

The coal deposits now being mined are the remains of vast forests submerged beneath the Earth's surface. Most of the world's coal was formed about 300 million years ago. As the mass of vegetable matter became buried under more and more sediment, the combined effects of intense heat and extremely high pressure turned it first into peat then into coal.

Oil is the fuel of 20th-century transport. Like coal, it is a fossil fuel, but it is largely the product of fossilized marine lifeforms which have been buried below the sea bed to a depth of around 2 km. Usually, oil and gas are found trapped under nonporous shale, clay or dense rocks, such as limestone.

Mining for oil involves drilling wells deep into the crust to pierce the top of the trap containing it. The drill bit is lubricated with water or mud. When the drill hits a deposit, pressure within the well often forces the oil or gas to the surface.

How radiation from nuclear power stations get into humans



Mark Franklin

On 26 April 1986, operators of the nuclear plant at Chernobyl in the then Soviet Union were conducting an unauthorized experiment when the reactor went 'critical' – out of control – and exploded, releasing an enormous cloud of radioactive debris. Human errors like these have done little to further public confidence in the nuclear industry.

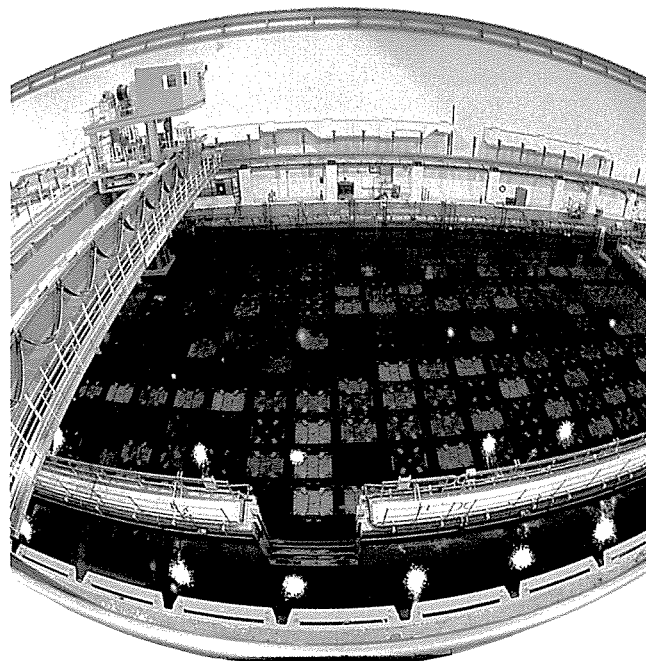
On the move

Another major area of concern is the transport of radioactive material. In Britain, for example, spent fuel rods are carried by train from power stations for reprocessing at a special plant. Reprocessing is necessary because during the fission process, the uranium is transformed into plutonium and waste materials. The reprocessing plant extracts the plutonium and any remaining uranium for future use, leaving the waste to be disposed of.

The spent fuel rods are trans-

Radioactivity can enter the environment in small doses over many years, or in large bursts by accident. This highly dangerous pollution can then pass into humans by any of a number of routes.

A storage pond for spent nuclear fuel awaiting reprocessing. The fuel elements are transferred from metal flasks in which they are transported, then lowered by an overhead crane into the water.



Mere Words/SPL

ported in leak-proof flasks 2 metres high, 2½ metres long, 2 metres wide and weighing 50 tonnes. To reassure the public, the UK's Central Electricity Generating Board (CEGB) staged a crash of one of

these flasks in the summer of 1984.

In full view of the press, television and public, a 140-tonne diesel train pulling three coaches was driven into a flask with an impact speed of 160km/h. The crash wrecked the train and threw the flask about 60 metres from the crash site – but the seals of the flask remained intact. During the past 35 years, the UK has moved more than 30,000 flasks of radioactive fuel.

Home-made nukes

One frequently expressed fear is whether a terrorist organization could steal material to make an atomic bomb. Each year, small amounts of nuclear material go missing. In 1965, for example, a check at the US reprocessing plant at Apollo, Pennsylvania, revealed that 94 kg of weapons-grade uranium had vanished from stock.

Missing material is thought to be

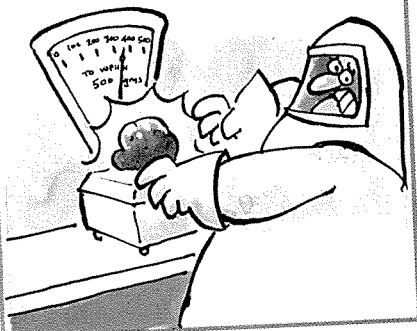
diverted to countries such as Israel, Pakistan, India, South Africa and China. If terrorists get hold of material such as plutonium, it is possible that they could indeed build a gun-type nuclear weapon.

Martin Bond/SPL

Just amazing!

A BIG BANG

PLUTONIUM-239 MUST BE STORED OR HANDLED IN QUANTITIES OF LESS THAN 300 GRAMS – ABOUT THE WEIGHT OF A FIST-SIZED ROCK. HEAVIER AMOUNTS EXPLODE AS A NUCLEAR BOMB.



Paul Raymond

A metal flask (white), into which spent nuclear fuel is transported by rail from nuclear power stations. The flasks are highly reinforced so they can withstand the impact of a crash without bursting. The useful part of the material is removed at a reprocessing plant, then the waste is stored in sealed containers.



THE EXTREME DANGERS involved in producing nuclear energy make the very highest standards in safety and security vitally important.

The production of nuclear energy in modern nuclear power stations relies on fission – the splitting of an atom into two roughly equal parts. Uranium-235 (U-235) is the form of uranium (called an isotope) most commonly used to achieve fission.

Atomic bullets

Electricity is generated from the heat produced when fission occurs in a chain reaction (a continuous process in which neutrons – nuclear particles – released by the fission of one atom go on to split other atoms). This heat turns water into steam, which powers the turbines that generate the electricity.

The major problem with nuclear power generation is not only that the U-235 is radioactive, but that the fission process produces other radioactive substances, and this radioactivity can be lethal. The greatest tasks in the nuclear industry are to contain the radioactivity – even in the event of an accident – and to control the chain reaction so it does not release all its fission energy in one surge – like a nuclear bomb.

Cooling the core

The uranium fuel is in the form of pellets packed into stainless-steel rods. This type of packaging helps the fission process, and it also makes the material easier to handle. The fuel rods are grouped together inside the core of the reactor – the vessel in which controlled fission takes place. The core and its associated cooling system are contained in a thick concrete pressure vessel, which in turn is housed in a concrete building.

On 28 March 1978, at the Three Mile Island nuclear power plant in the USA, a failure in the reactor cooling system, combined with operator mistakes, severely damaged the reactor, releasing radioactivity into the atmosphere.

NUCLEAR SAFETY

A nuclear bomb set off in the Nevada Desert, USA. In nuclear power stations, this tremendous amount of energy is released in a controlled way to produce steam for generating electricity.

Remote handling gear, controlled by staff using computer consoles, is used to unpack spent nuclear fuel elements (which are still highly radioactive) before they can be reprocessed.

(GPS) began operating in the early 1990s. Then any ship, plane or car anywhere on Earth with the right onboard equipment will be able to find its true location to within about 100 metres.

The A320 airliner (the European Airbus) bristles with 'smart' electronics. Microprocessors — miniature computing units — built into the wings supervise the motors that operate the flaps and slats. By turning the flaps down or pulling the slats out, the pilot can give the Airbus increased lift. But if the pilot makes an error — for example, tries

A global positioning map being used as part of a computerized navigation system to track patrolling military aircraft around the world.

Robot trains on the light railway system in Lille, France. Controllers monitor the progress of the trains, which run at one minute intervals, via computer terminals and video screens.



advantage of computer power — they are designed to be unstable to make them more agile. A test version of the British Aerospace Jaguar built in this way, for example, is 15 per cent lighter than a standard Jaguar and 20 per cent more responsive in turns. So it has a great advantage in aerial dogfights.

The problem with such an unstable plane is that no human pilot can fly it unaided. So, computers throughout the aircraft monitor every moving part many times each second, changing the control surfaces on the wings and tail as needed.

● Fly-by-wire

With computers on hand, the pilot need never worry about going into a spin or swerving too fast. Even if he slams over the control stick too hard in the heat of combat, the 'fly-by-wire' system works out the steepest turn or climb that can be made without overstressing the aircraft, then responds in a split second to maintain a safe pattern of flight.

Computer control can make outmoded technologies once more attractive. A new generation of wind-assisted vessels is taking to

the high seas, not with a large crew of sailors to set the sails, but with computers.

Pioneer of this approach to ocean transport is the Japanese tanker, *Shin Aitoku Maru*. Its two rigid sails, over 12 metres high and 8 metres wide, are canvas over a steel framework. On board, a system of computers adjusts the sails for best performance, throttling back the ship's diesel engine according to the force of the wind.

Ivaldi/Jerrican

DRIVERLESS TRAINS

At Lille in France, fully automated commuter trains work safely and efficiently without a human driver at the wheel.

Computers keep track of the trains' positions and control both acceleration and braking to keep trains running exactly one minute apart during rush hours.

Staff in a central control room supervise the entire network, working with closed-circuit TV screens, an electronic chart of the rail system and computer consoles. By remote control, they can quickly deal with any problems or bring more trains into service to meet extra demand.

Peter Ryan/SPL

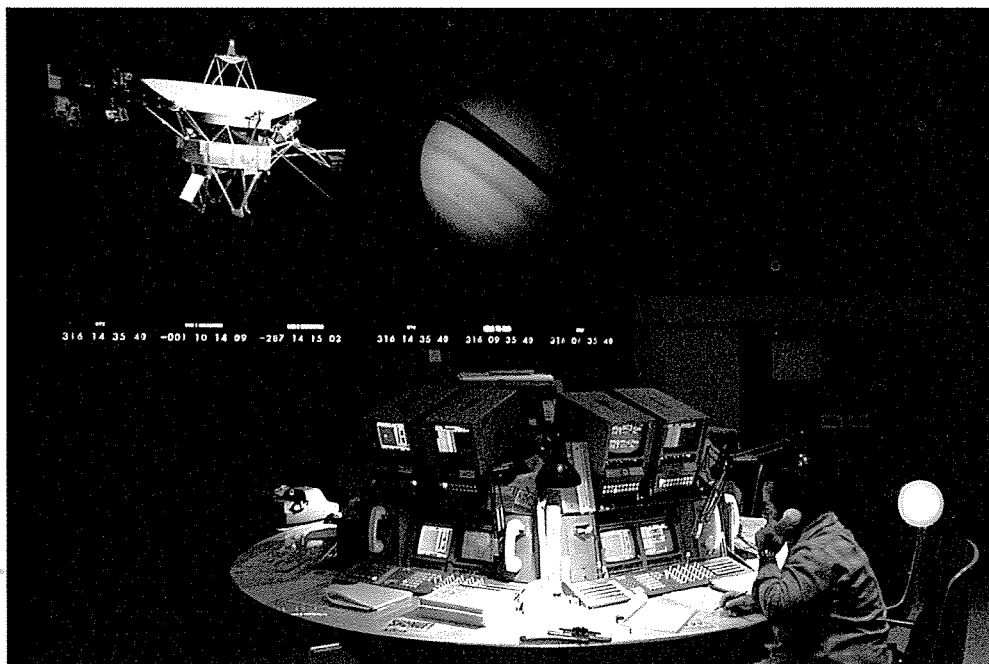
to pull back the slats below a safe speed — the microprocessors warn the flight crew that this action could be dangerous. The captain then has the choice of cancelling the procedure or repeating it to override the computer.

● Active control

By the next century, there could be helicopters flying without human pilots in control. Passengers would simply tell a master computer on board where they want to go and the helicopter would take off, fly safely to its destination and land automatically.

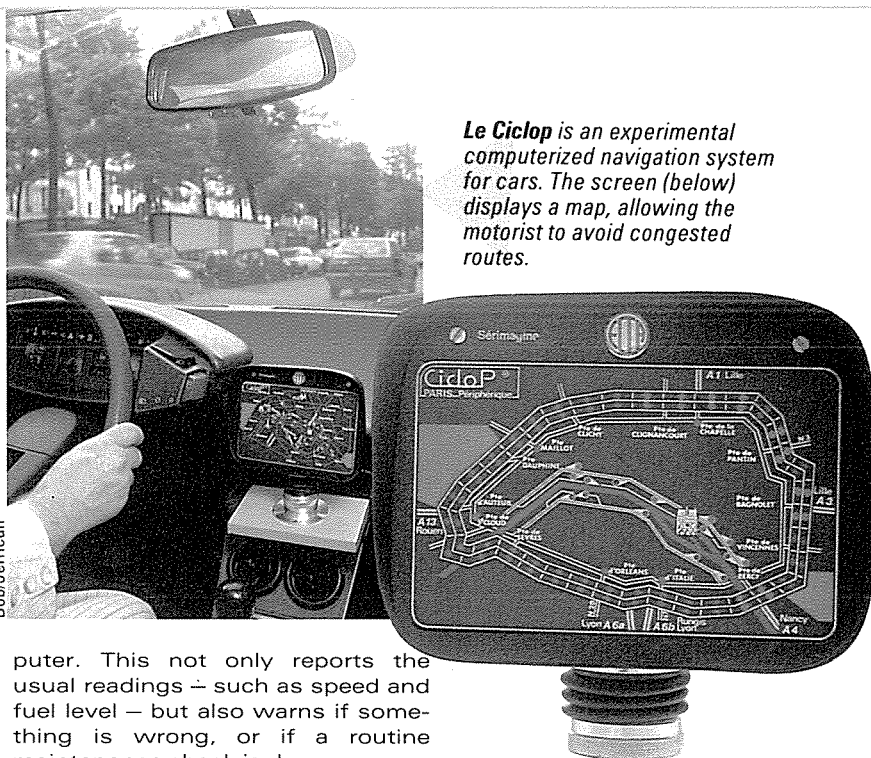
The latest fighter planes take

Mission control at the Jet Propulsion Laboratory, California, USA, during the monitoring of the progress of the Voyager 1 spacecraft's encounter with the planet Saturn in November 1980.



Eric Schulzinger/Lockheed Aeronautical Systems Co.

Bob/Jerrican



Le Ciclop is an experimental computerized navigation system for cars. The screen (below) displays a map, allowing the motorist to avoid congested routes.

puter. This not only reports the usual readings – such as speed and fuel level – but also warns if something is wrong, or if a routine maintenance check is due.

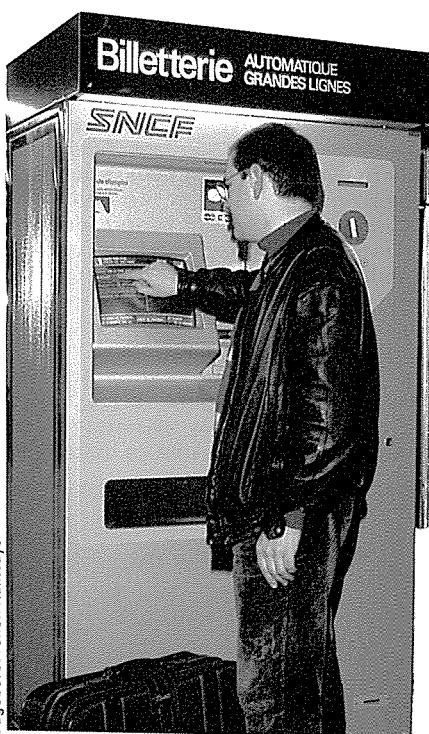
Soon, car computers will be able to do 'smart' gear changes. As the driver shifts the four main gears, a computer will control three more intermediate gears for smoothness and better fuel economy. The shifts will be so quick that those in the car will not be aware of them.

Intelligent cars

Within ten years the onboard car computer will bring many automated refinements. For example, cars may be able to sense and respond to rain. When drops of water start to fall on the bonnet, pressure sensors will alert a computer to turn on the windscreen wipers. Similar devices in the passenger compartment will alter the shape of seats automatically to suit whoever is sitting in them. Computerized rear-view mirrors will adjust themselves to day and night driving.

Imagine you are driving a car

Computerized ticket machines are a feature of railway booking halls throughout the world. The latest versions can issue change from banknotes.

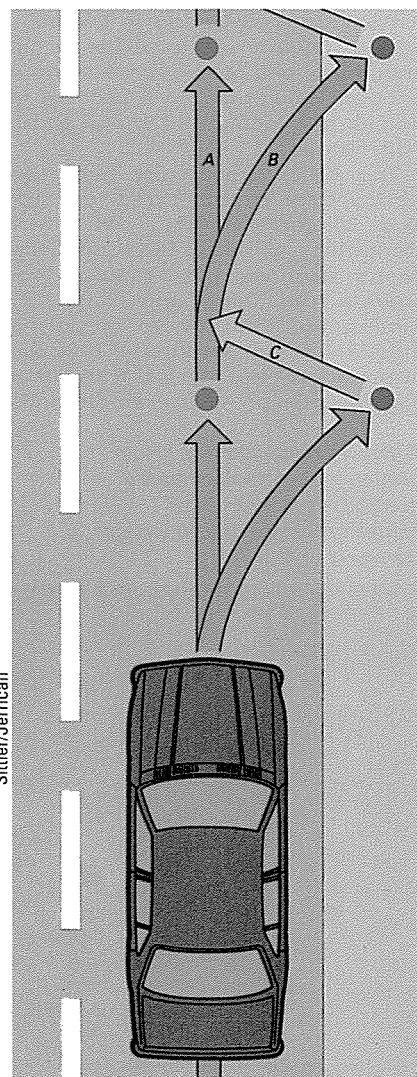


Dagobert/French Railways

fitted with a computer that acts as your guide. On the dashboard, you see a small TV screen displaying a street map, with a blinking light to mark your position. At the appropriate moment, instructions appear on the screen and, if desired, are 'spoken': 'Leave the motorway at the next exit. Then take the first turn left'.

Early warning

Some car navigation systems are already available. One called Carin, under development by the Dutch company Philips, can hold as much



Sittler/Jerrican

Philips Carin

Carin is a satellite navigation system. The correct route (A) is constantly checked and any steering errors (B) instantly corrected (C).

information as a shelf full of ordinary road maps. Eventually, the system will be able to pick up messages beamed from roadside beacons that will warn of traffic delays. Then the computer will plan routes to avoid them.

Such systems work out distances by measuring how many times the car's wheels have turned around, and find directions by taking readings from a compass. In the future, car travellers will be able to pinpoint their positions far more accurately by using satellite navigation systems.

Signals at sea

Already, ships use this method to find their way at sea. A computer on the ship's bridge picks up signals sent out by a number of satellites in Earth orbit. The computer then calculates the vessel's position at any time of the day or night.

A network of 24 satellites, known as the Global Positioning System

Just amazing!

CAPTAIN CHIPS

ON JANUARY 15, 1985, A COMPUTER SAFELY PILOTED A DUTCH FREIGHTER TO WITHIN A FEW KILOMETRES OF ITS DESTINATION – THE CREW HAVING ABANDONED SHIP TWO DAYS PREVIOUSLY.



Paul Raymonde

Ultra-light composites clad the alloy airframe of the EAP. Aft are two RB 199 Mk.104 turbofan engines with afterburners.

centre of gravity, or point of balance, towards the rear of the airframe

foreplanes can be angled to control pitch and improve stability

engine air intake designed to minimize drag, or air resistance

flaperons, or wing flaps, in twin sections control pitch (raising and dipping of the nose) and roll (turning over wing to wing)

rudder controls yaw (pointing of the nose from side to side)

leading edge flap varies lift and gives added stability at different speeds

British Aerospace Military Aircraft

wheels. Each of the sensors monitors the speed of a wheel and sends this information to the computer. In a flash, the computer analyses the data from the sensors, decides if any of the wheels is about to lock, then tells the braking

suspension system which uses a computer linked to sensors on each wheel. The sensors detect when the car goes over bumps in the road and send signals to the computer, which works out how much to soften the suspension. It all happens so quickly that the passengers are totally unaware of any roughness in the road.

As well as giving a comfortable ride, the active system makes cornering safer. It can stiffen the

car's suspension on a sharp bend or make the car lean into the bend, so countering the effects of centrifugal force on the occupants. The system also tilts the car forwards when the driver accelerates quickly and tilts it

COMPUTER ERROR

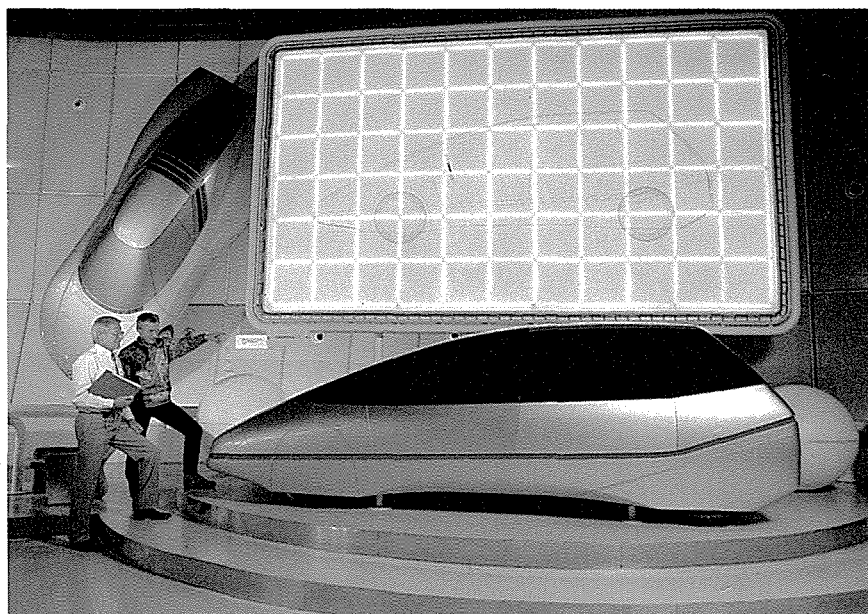
On February 19, 1985, China Airlines Flight 006 was cruising on autopilot at a height of more than 12 km bound for Los Angeles, USA. Suddenly, without warning, the jumbo jet began to fall from the sky, plummeting more than 9 km in just two terrifying minutes before the pilot regained control.

An analysis of the plane's flight recorder revealed later what had gone wrong. The outer engine on the right wing had lost power. And although a Boeing-747 jumbo jet can fly manually on only three engines, it cannot do so with the autopilot engaged. The captain made the almost-fatal mistake of not taking over from the autopilot straight away – one instance of where the human, not the computer, should have been in charge.

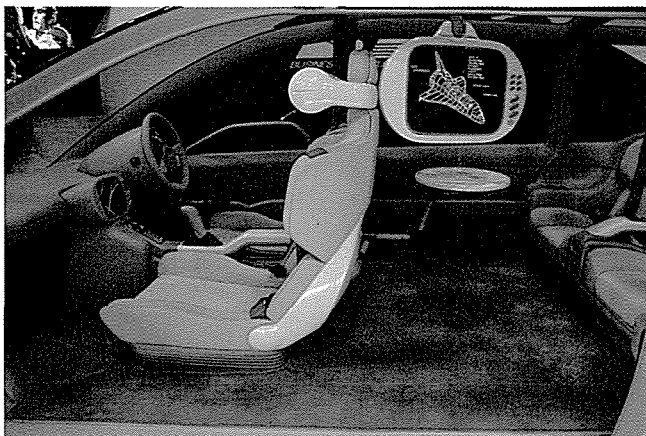
system to briefly release the wheel.

The computer does what every driver ought to do on a slippery road – it applies and releases the brakes rapidly to avoid a skid. The difference is that the computer can be relied on to do it perfectly every time – and up to ten times a second.

The British sports-car manufacturer, Lotus, is testing an active



Ivaldi/Jerrican



Sautetel/Jerrican

BMW's prototype car of the future owes its special aerodynamic shape to CAD (computer aided design).

Subaru's experimental car relies on its in-built computer for active control of every function, from the engine and suspension to air conditioning.

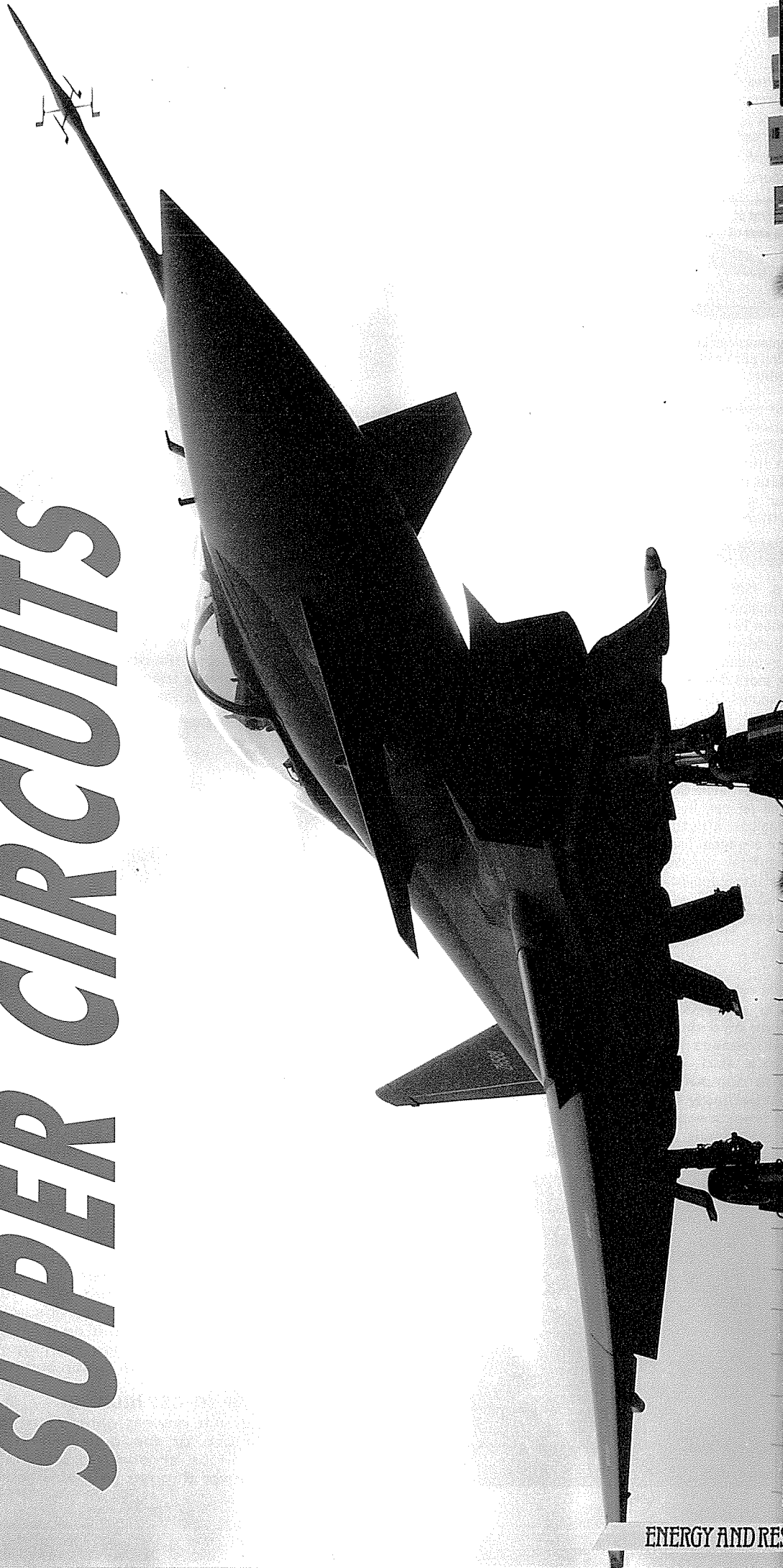
back during hard braking, once again countering the forces of motion.

Engine performance, too, is being monitored by computer on the latest models of cars. The computer checks the amount of fuel and air entering the engine, ensuring that the mixture is just right to achieve peak performance with good fuel economy and pollution control.

In-car monitor

In the newest generation of cars, much of the data picked up by various sensors is relayed to the driver through an instrument com-

SUPER CIRCUITS



Q NAVIGATION

Q SAFETY FEATURES

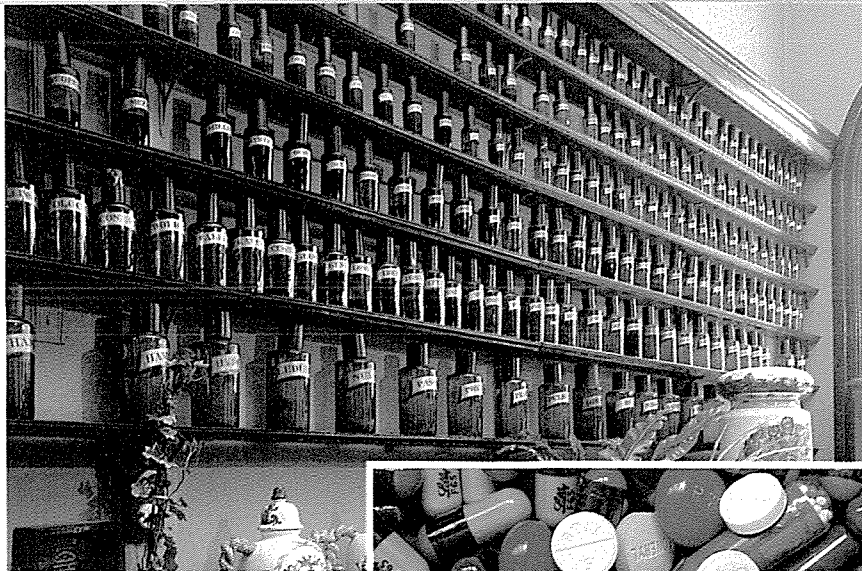
Q AUTOMATIC CONTROL

NOWADAYS COMPUTERS ARE revolutionizing every mode of transportation — from the cars, ships and planes that traverse the Earth to robot spacecraft that fly to distant planets. As in every other sphere of life, the magic of the microchip is endowing vehicles with intelligence.

Imagine a car in the dead of winter, speeding along a country lane splattered with sheets of black ice. Suddenly, a child darts out into the road ahead. The driver slams on the brakes. Surely catastrophe, but no — the car stops quickly and safely. The reason is anti-lock brakes.

Anti-lock computers are linked to four electronic sensors behind the

The Euro Fighter built by a group of West European countries, is designed to be unstable so it responds rapidly to the computerized fly-by-wire signals that control it.



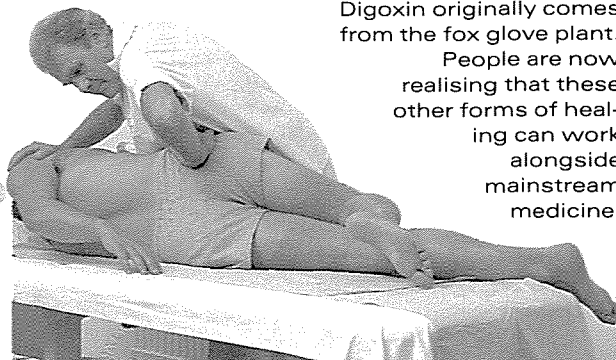
Herbalism is one alternative to the use of modern drugs (right). Many people suffer from side-effects or allergies when treated with modern medicines and they may find relief with herbal cures. But, in fact, many drugs are originally derived from herbal extracts.

Osteopathy aims to relieve aches and pains by manipulating the body, especially the spine, joints and muscles. Its founder, Andrew Still, believed that many illnesses were caused by impaired nerve and



Adam Hart-Davis/SPL

Osteopaths treat their patients by manipulating the spine, joints and muscles. Although it looks painful, this form of treatment is highly effective – particularly for back problems. It is based on the principle that some injuries are caused by impaired blood flow or cramped nerves.



Digoxin originally comes from the fox glove plant. People are now realising that these other forms of healing can work alongside mainstream medicine.

CHINESE MEDICINE



Paul Biddle & Tim Matyom/SPL

Acupuncture is based on an ancient Chinese form of treatment, which uses, among other things, needles inserted into the skin to cure illness and injury. (This woman is being treated for headaches.) The ancient Chinese believed that energy flowed along channels called meridian lines in the body and that needles could be used to release blockages on these lines. A modern version is that the meridians correspond to the branches of the nervous system. Because the meridians run the length of the body, the acupuncture points may be far from the affected area. Acupuncture can also be used sometimes as a form of anaesthetic for operations.

blood-flow, because the spine was out of place. Osteopaths must undergo several years full-time training at an approved college before they are registered.

Chiropractic is similar to osteopathy but is based on misplaced vertebrae disrupting the nervous system, and some of the manipulative techniques are different. Naturopathy is concerned with an holistic approach. This means looking at the body as a whole rather than specific symptoms. A naturopath believes in the body's innate ability to heal itself and will concentrate on the patient's lifestyle and diet. Often, a medicine-free regime is formulated, based on changes in diet, vitamin and mineral supplements. Hydrotherapy (treatment by hot and/or cold water) may also be used.

Like heals like

In homoeopathy, the idea is to stimulate the body's natural defences against disease by promoting a mild form of the disease. To do this, small doses of 'natural' drugs are administered. For example, the deadly nightshade berry is poisonous, producing a red flush similar

to scarlet fever. But homoeopathic doctors see the flush as a sign that the body's defence is working. So to fight scarlet fever, they would administer tiny doses of deadly nightshade extract and leave the body to cure itself. It was also discovered that the more the active substance is diluted, the more effective the homoeopathic remedy becomes. This is opposite to orthodox medicine where a stronger dose produces a stronger effect. So although some homoeopathic preparations can be poisonous in large doses, they are prescribed in such minute amounts that they are completely harmless.

Ancient and modern

Herbalism uses herbs to treat disease, often in the same way as drugs. The combinations of herbs have been passed down from generation to generation and were originally the result of trial and error. Many modern drugs have their origins in herbal medicine. For example, the active part of the heart drug

Digoxin originally comes from the fox glove plant.

People are now realising that these other forms of healing can work alongside mainstream medicine.

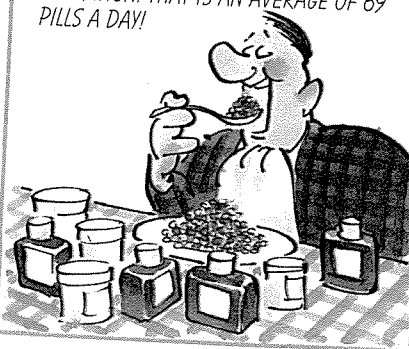
In the future, they may be incorporated in the health service. This would prevent much patient suffering and save a lot of money, which could then be channelled into research for the prevention of diseases.

ZEFA

Just amazing!

PILL-POPPER

THE RECORD FOR PILL SWALLOWING WAS A TOTAL OF 555,439 BY C. KILNER OF ZIMBABWE BETWEEN JUNE 1967 AND JANUARY 1988, FOLLOWING A PANCREAS OPERATION. THAT IS AN AVERAGE OF 69 PILLS A DAY!



Paul Raymonde

ANTIBIOTICS

ALTERNATIVE HEALING

ACUPUNCTURE

HEALING IS THE MAGICAL process by which the body recovers from illness or injury. Often our minds and bodies work together to repair themselves naturally. But sometimes healing needs to be helped by one of many different forms of medicine.

Medicines used to stop pain, such as Aspirin and Paracetamol, are called analgesics. Analgesics do not cure diseases, but merely suppress the symptoms.

● Drug side-effects

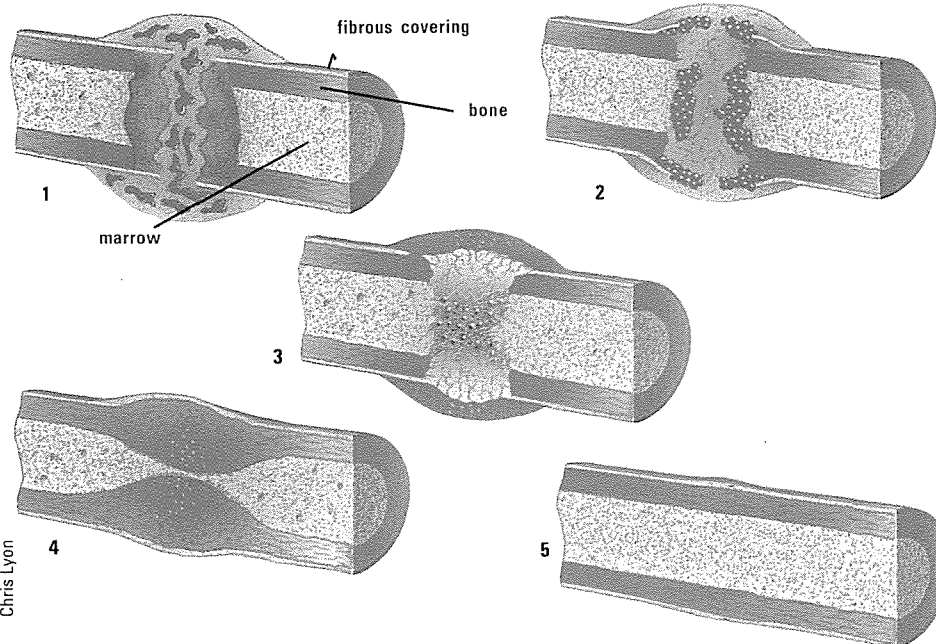
Antibiotics form another important group of medicines, which kill off the bacteria that cause some illnesses. They work by altering either the metabolism or cell walls of the bacteria. Penicillin is a widely used antibiotic which is derived from a type of mould and was discovered by Sir Alexander Fleming in 1928.

But one problem that many people find with taking drugs to fight illness is that they suffer from allergic reactions or adverse side-effects. This is why more attention is being directed towards alternative forms of medicine, such as osteopathy, chiropractic, naturopathy, homeopathy, acupuncture and herbalism.

Bacteria under attack. These bacteria, which cause boils and abscesses, are being destroyed by antibiotics. The antibiotics break down the cell walls, causing the bacteria to fragment (top).

CNR/SPL

HEALING FORCES



Chris Lyon

When a bone breaks, the blood vessels running through it break too, causing bleeding and swelling. But it is the clotting of the blood which forms the 'scaffolding' for the repair of the bone (1). After about one week, bone cells from the broken ends start to spread into the clotted area, or callus (2). After three weeks, bone cells help form fibrous tissue, which unites the two ends (3). Later on, the finished join has a mass of bone around the site of the break and is still slightly swollen (4). After several months, the bone will smooth itself out, so that it returns to its original thickness (5). The break can then only be detected by X-rays.

quality — is cultivated in under-sea shelters.

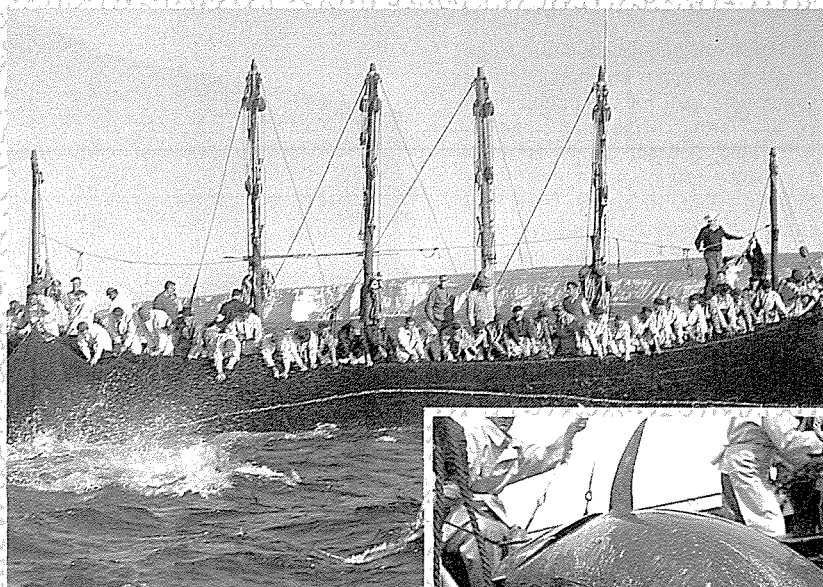
Around the world, fish farming produces about 15 per cent of all fish eaten. The industry is growing at more than five per cent each year. But compared to farming on dry land, it is still in its infancy.

● Fish farms

Fish farmers now want to do with fish what land-based farmers did with cows and sheep centuries ago — breed them selectively to produce bigger, more docile, more productive 'domestic' strains. In Norway, in a huge research programme, scientists selected various strains of fast-growing salmon and inter-bred them. Over three generations, the salmon's growth rate went up 12 per cent in each generation.

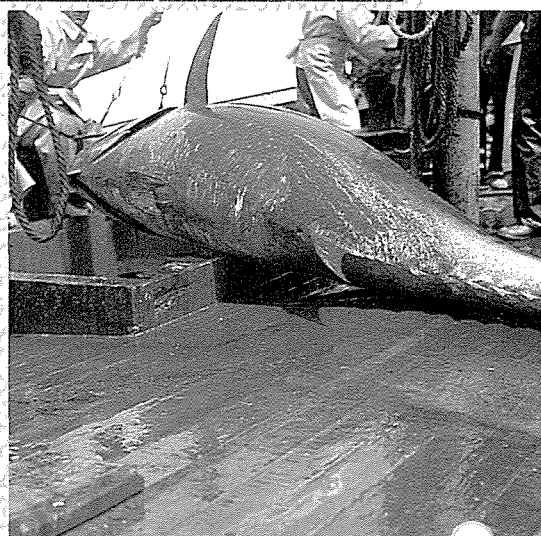
But there have been few other successes. This is partly because fish growth, and the eventual size

TUNA — BLOODED, BOILED AND TINNED



Tuna is one of the world's favourite fish. The Japanese — who eat it raw as sashimi — take around 60 per cent of the world's catch by stringing miles of baited hooks out behind their boats.

Here, Spanish fishermen use an older, more bloodthirsty technique. Boats surround a shoal, string a net under them and haul it up until the sea is a frothing mass of thrashing fish. The trapped tuna are then blooded with boat hooks.



Huge modern trawlers use massive pumps to almost literally 'hoover' fish off the sea floor, leaving little living behind.

of an individual fish, seem to depend on so many factors. These include how aggressive the fish is at getting food, its resistance to disease, how much food is available and how crowded its pond is.

If a researcher or farmer wants to set up detailed breeding experiments, he must be able to identify individual fish. Notching fins, spotting fish with dye and branding their scales have all been tried.

A newer method involves a tiny electronic device called a transponder which is injected into the fish's belly. When the transponder is set off by waving a special 'magnetic

wand' nearby, it sends out a 10-digit coded signal.

Fish farmers would like to breed fish that could convert their food to flesh more efficiently, that could survive in water that is more crowded and, thus, has less oxygen, and that are easy to catch and process.

Genetic engineers have been experimenting on fish in recent years. Although fish eggs are quite large when compared to eggs of mammals, the nucleus (the central part where the genes are) is very small. This makes it difficult for the technician to inject genes directly into the nucleus, so adding genes to a fish egg is a very hit-and-miss business. However at Auburn University, Alabama, USA, genes for growth hormone have been added to carp eggs. The resulting fish grew 20 per cent more quickly.

● Anti-freeze

Some fish, such as the winter flounder, have 'anti-freeze' in their body fluids. This means they can withstand extremely low temperatures. Salmon in farm cages sometimes freeze to death because they lack that anti-freeze. So scientists are researching whether the flounder's anti-freeze gene could be added to the salmon to help it survive the extreme cold.

Fish tagging is important for researchers and farmers — only if individual fish are marked can they check on growth. This visible tag is inserted into the transparent tissue around the eye using a syringe or tweezers. Manufacturers claim only five per cent fell out.

Fish Eagle Co

Jesus Perez/Planet Earth Pictures

MISMANAGING THE SEA

Our seas are being fished out. Huge trawlers use sonar equipment to find shoals and vast nets to scoop them up, 'hoovering' the sea bed clean.

In 1965, 250,000 tonnes of haddock were caught in the north-west Atlantic. Just 10 years later, the catch was less than one-tenth of this. In the Pacific, the anchovy catch plummeted from 12 million tonnes in 1971 to two million tonnes a few years later. The story has been the same the world over.

The seas are also filling up with our chemical wastes. More than four-fifths of polluting chemicals in the sea come from land, flowing out along rivers. On average, six million tonnes of oil enter the sea each year. We may hear about accidental oil spills from tankers, but more than half of the annual oil pollution is washed down the rivers. Dangerous heavy-metal chemicals (such as mercury) now occur in the sea at many times their natural levels.



Liaison/Frank Spooner Pictures

Robert Jureit/Planet Earth Pictures



nearly 30,000 tonnes by 1990. Norway raises even more salmon. Iceland, Canada, Chile and Ireland are also developing their salmon-farming industries.

In Scotland, most of the suitable sites are now fully occupied by fish. So scientists are looking at the possibility of keeping salmon in huge cages out at sea.

Bad weather

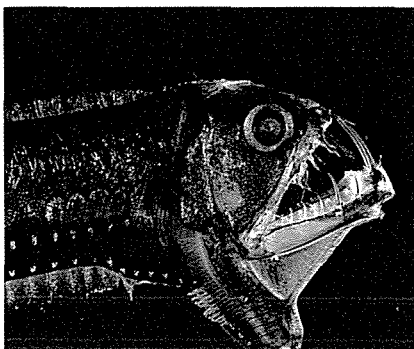
The test cages are 25 metres across and hold about 40,000 young salmon, which are called smolts. The cages float mostly submerged. A computer-controlled hopper contains three tonnes of food, enough to feed the fish if farmers cannot reach them for a few days due to bad weather.

Sensors in the cage monitor conditions and send signals along a cable to shore, while video cameras record the salmon's movements.

Unfortunately, fish cages in lakes or near the coast create problems. As well as interfering with pleasure craft and water-users, the fishes' waste tends to build up, as there are no strong currents to sweep it away.

Offshore cages, with good water circulation, should not suffer from these problems. On the other hand, the cages' meshwork might become encrusted with weeds and marine animals. Also a big storm could rip them open and set the salmon free.

These ugly fish may soon be accompanying your chips. The Viper fish and the Anglerfish (right) are nutritious and plentiful in the ocean depths, but they don't look very appetizing.



Peter Parks/Oxford Scientific Films



ZEFA

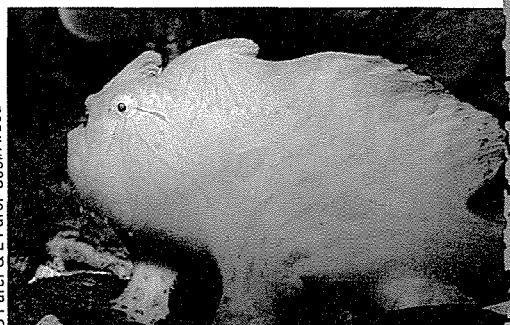
Oysters beds have been farmed in Japan for 300 years. Oysters need protection from strong currents (inset).

In addition, the flesh of caged salmon is not rosy pink, like that of wild salmon, but 'hatchery grey'. To counteract this, some farmers add a synthetic colouring called canthaxanthin (E161g) to their fish feed. However, this additive is banned in the USA.

Turtle ranch

Sole and plaice farms have been built to take advantage of the warm water discharged from coastal power stations. In the Cayman islands, there is a turtle ranch. This was begun in an attempt to save the green turtle from extinction. But turtles are so productive, when their young are protected from natural predators, that the ranch now sells off turtles to make soup.

Oysters, shrimp and lobsters are all farmed and abalone – renowned as the 'filet mignon of the sea' because of its delicious steak-like

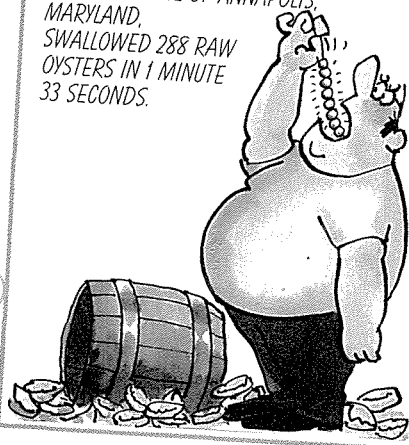


D Parer & E Parer-Cool/Ardea

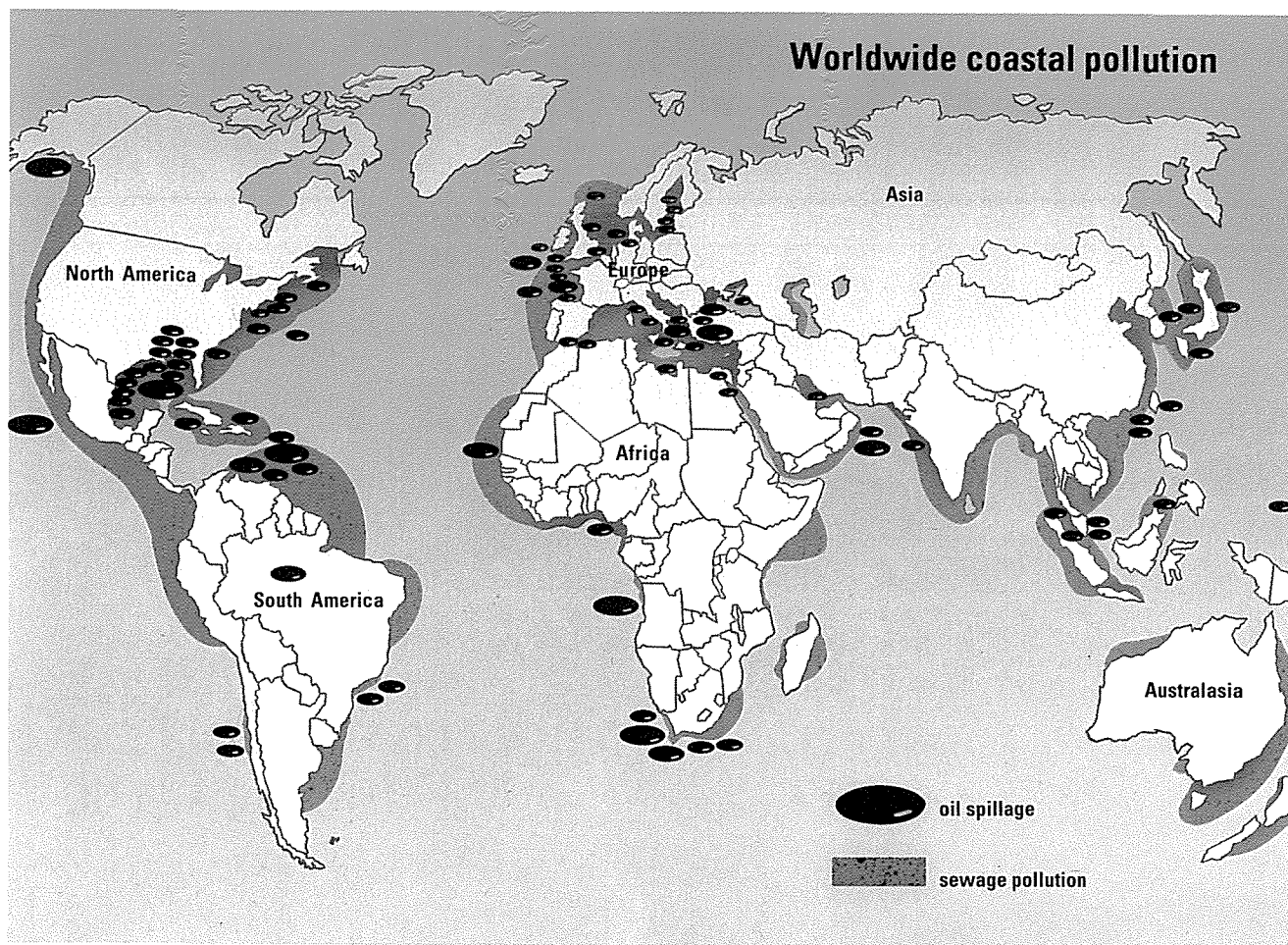
Just amazing!

PEARLS BEFORE SWINE

TOMMY GREENE OF ANNAPOLIS, MARYLAND, SWALLOWED 288 RAW OYSTERS IN 1 MINUTE 33 SECONDS.



Paul Raymond



Industrial waste and sewage pollute much of the world's coast lines. Oil-spills take their toll on both coastal waters and the deep ocean.

sea fish we consume comes from the continental shelf. In future, could the deeper parts of the oceans yield new kinds of fish to have with our chips?

Some countries are already exploiting the deep. New Zealand fishermen are trawling for a deep-sea fish called the orange roughie. This creature is 50 cm long and orange in colour, with spiny fins and a wide mouth. Trawlers can catch up to 50 tonnes of orange roughie an hour. Since 1980, over 40,000 tonnes of orange roughie have been caught. This fish is important not only for its flesh, which is tasty, but for the waxy oil in its swimbladder, bones and other parts of its body. Orange roughie oil can be used in cosmetics to replace oil from endangered sperm whales. It is a good lubricant and can also be incorporated into textiles and polishes.

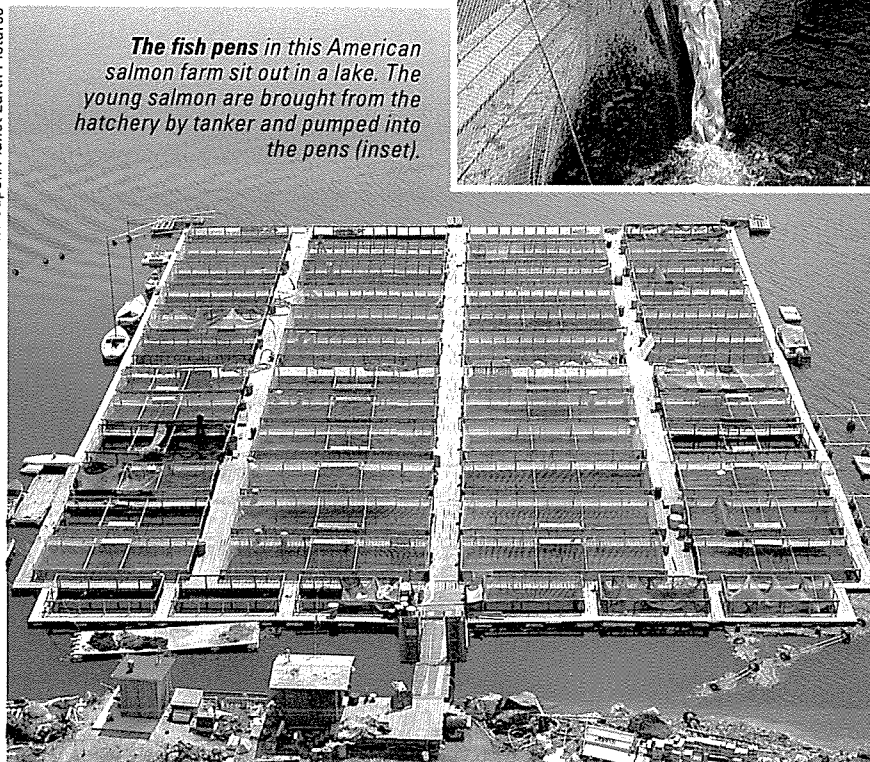
Rat-tails

One disadvantage of trawling at depths of over 1,000 metres is that it takes much longer to lower and raise the net, so fewer can be made each day. Another problem with deep-sea fish is their often strange

appearance and peculiar names — both of which can be distinctly off-putting. For example, Soviet fishermen catch about 7,000 tonnes each year of a deep-sea fish we call the blunt-nosed rat-tail. It is difficult to imagine eager customers asking for 'rat-tail and chips' at their local chippy.

Meanwhile, fish farming, or aquaculture, is rapidly expanding. Scotland's salmon farms produced 2,000 tonnes of fish in 1970 and

The fish pens in this American salmon farm sit out in a lake. The young salmon are brought from the hatchery by tanker and pumped into the pens (inset).



TRAWLING THE DEEPS

FISH FARMING

POLLUTION

AQUACULTURE

Salmon reared in man-made ponds can be fed well, protected from predators – and caught much more easily.

THE SEA CAN BE FARMED, just as the land can and fishermen – the 'farmers' of the sea – experience many of the same problems as their land-based counterparts: overproduction, pollution and the search for new crops.

There is nothing new in farming the sea, of course. For thousands of years people have caught fish and harvested seaweed – or kelp – for food and other purposes. Shark skin makes excellent sandpaper, while the rough scales of the strange coelacanth, a 'living fossil' fish from south-east African waters, are used by local people to roughen their bicycle inner tubes before sticking on a puncture patch!

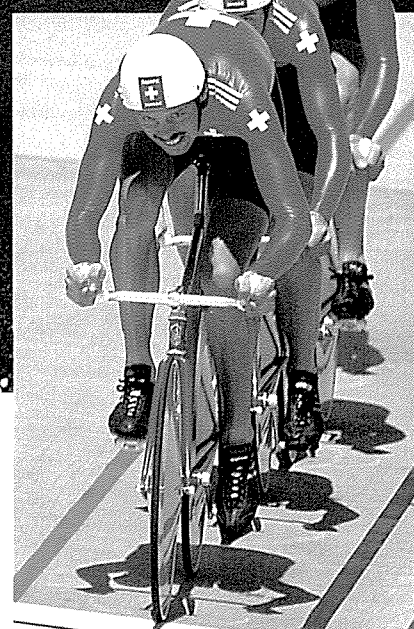
On the shelf

Much of the fish we usually eat come from the relatively shallow waters over the continental shelf. Only a few hundred metres deep at most. The continental shelf surrounds the main continents. In volume, the seas there make up less than ten per cent of the water in the oceans. Yet 95 per cent of the

In the hatcheries, fish eggs are stripped from the mother. They are incubated in conditions that ensure nearly every baby salmon survives.

Keith Gunnar/Bruce Coleman Ltd

SUPER CYCLING



Mike Powell/Allsport

COMPETITIVE CYCLING IS ONE of the fastest-growing sports of the 1990s. To succeed at the highest level, the cyclist must be in peak condition. He or she also needs a precision-crafted machine that may cost almost as much as a small car.

A specialized road-racing bike may look like a standard sports bike, but there are several differences. First, there is the frame. It has to be strong and light, but also flexible enough to cope with the twists and turns of racing. The most popular material is chrome-molybdenum alloy steel, between 0.7 and 1.0 mm thick. Weight is saved by a process called

The Tour de France is the longest-lasting sporting event on land in the world, taking 21 days to complete. The 4,000 km course over both flat and mountainous terrain demands speed and stamina. In tandem sprinting (right), riders race over a distance of about 1500 metres.

butting, which means the tubes are thinned out internally where the least strength is needed.

The really expensive machines have frames made of lightweight aluminium or titanium-alloy. The best frames are hand-made and weigh no more than about 2.5 kg. Expensive

titanium-alloys are also used for the accessories. The handlebars are usually made of duralumin alloy, about 1mm thick. This is an aluminium-based metal that is as strong and as hard as steel.

Tubulars

A racing bike's tyres, known as tubulars, have a carcass of fine cotton or silk sown around a very light inner tube. The outer surface is covered with a light tread, and the whole tyre is stuck on to the wheel rims with cement or special rim tape. All tyres perform best after they have been 'matured' for a year or more in a cool, dark room, lightly inflated on wheel rims. This hardens the tread.

Track bikes, used on single-lap tracks, have smaller and stronger frames to cope with the sideways stresses of speed cycling. They weigh between 6 and 8 kg, whereas a road-racer is typically 8.5 to 10.5 kg. Even lighter is the Lotus superbike, on which Chris Boardman won a gold medal for Britain at the 1992 Olympics. It has a one-piece carbon fibre frame.

Some track bikes are fitted with solid carbon-disc wheels to reduce wind resistance.

The tyres are sometimes filled with helium to lessen weight. Track machines have no brakes or gears and the back wheel cannot freewheel. Riders slow down by exerting backward pressure on the pedals or placing a gloved hand over the front wheel.

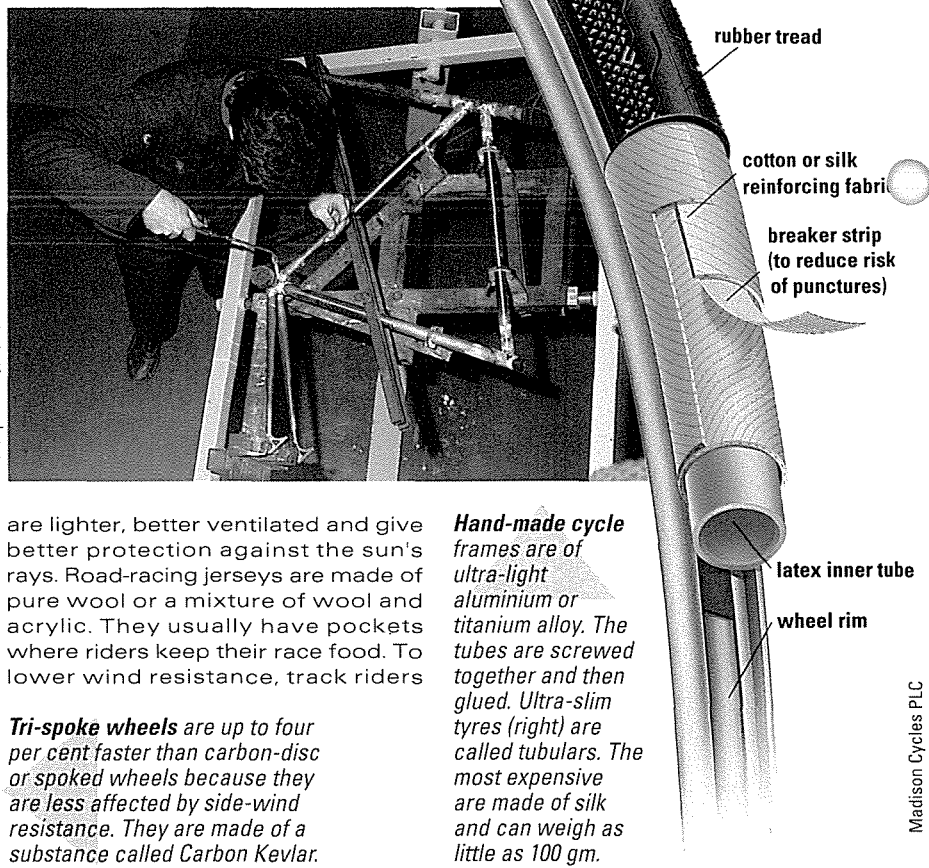


Gamma/Frank Spooner Pictures

Track events take place on a velodrome, which should have banked corners and be no more than 500 metres long. Track-racing consists of time-trials, sprints and team or individual pursuits. In pursuit racing, riders or teams start at opposite sides of the track, and the object is to overtake each other. If no one is overtaken, the winner is the fastest over the distance.

According to rules laid down by the Union Cycliste

Photosport International



are lighter, better ventilated and give better protection against the sun's rays. Road-racing jerseys are made of pure wool or a mixture of wool and acrylic. They usually have pockets where riders keep their race food. To lower wind resistance, track riders

Tri-spoke wheels are up to four per cent faster than carbon-disc or spoked wheels because they are less affected by side-wind resistance. They are made of a substance called Carbon Kevlar.

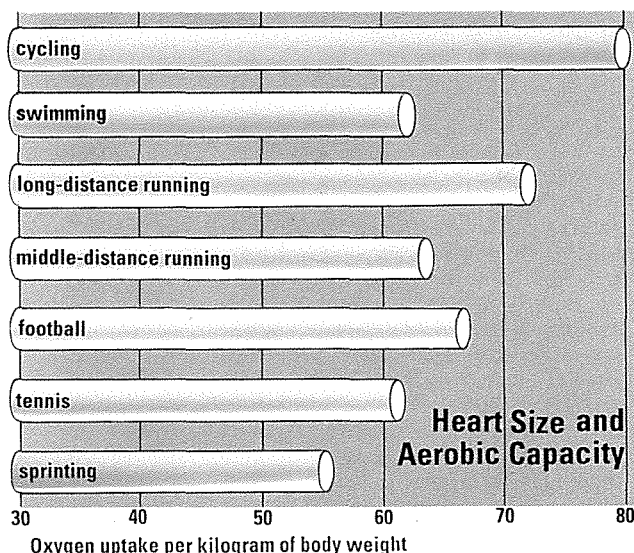
Hand-made cycle frames are of ultra-light aluminium or titanium alloy. The tubes are screwed together and then glued. Ultra-slim tyres (right) are called tubulars. The most expensive are made of silk and can weigh as little as 100 gm.

Madison Cycles PLC

Heart of an untrained person (600-700 cu cm)

Heart of a trained cyclist (1000-1400 cu cm)

Mark Franklin



Cycling is the best sport for achieving aerobic fitness. A racing cyclist's heart muscle increases in size during training – and may grow to twice that of an unfit person's heart.

taking part in time trials and circuit races wear silk jerseys or aerodynamic one-piece suits.

Feet first

The racing shoe is probably the most important item of equipment for the competitive cyclist. The uppers are made of soft box-calf leather and have holes to allow the feet to breathe. Most shoes have a leather sole with a steel, aluminium or plastic plate insert. This prevents the shoe from sliding around on the pedal.

THE BIG WHEEL

Italian cyclist Francesco Moser pioneered the use of carbon-disc wheels when he broke the world one-hour cycling record in 1984. These have now become the standard in record attempts and track-racing. But Moser has now gone one step ahead of the rest – he is using a bike with a rear wheel one metre in diameter. This allows him to use a more efficient gear ratio than normal. It also increases the gyroscopic effect (momentum) of the wheel, providing greater stability and a much smoother running bike.

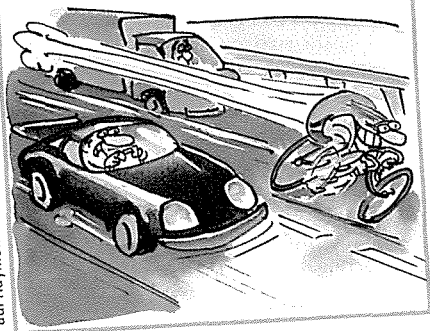
Even with a slightly larger front wheel than usual, the combined weight is still less than the wheels used in his 1984 record.

International (UCI), cycling's world governing body, all road-racing riders must wear cycling shoes, white ankle socks, short black racing shorts, a racing jersey and a crash hat or helmet. Crash-hats are made out of padded leather bars and are held in position by a chin strap. Plastic helmets that cover the whole head

Just amazing!

PEDAL POWER

THE FASTEST RECORDED SPEED BY A CYCLIST ON AN OPEN ROAD WAS 158 KM/H BY DAVID LE FRY'S ON A STRETCH OF THE M42 MOTORWAY, UK, IN 1985 - ALMOST 50 KM/H ABOVE THE LEGAL SPEED LIMIT!



Paul Raymonde

ON TARGET

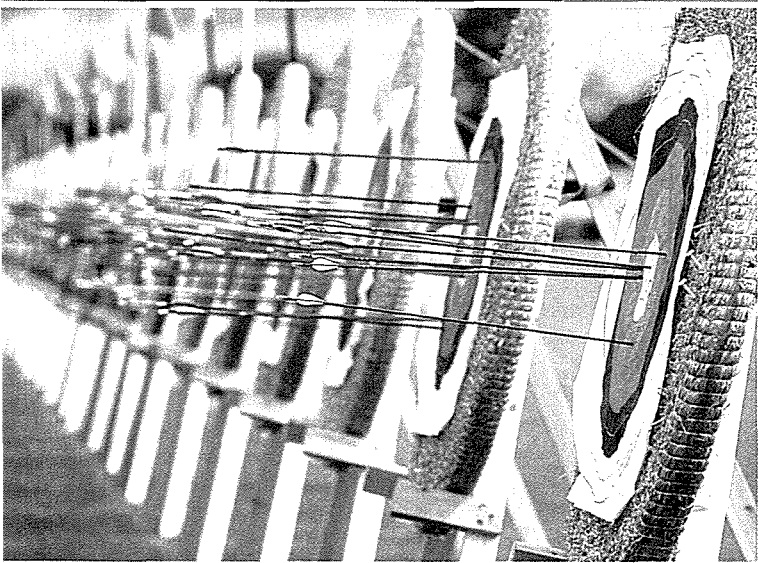
TARGET SHOOTING IS ONE of the oldest and most popular participatory sports in the world. From archery to air-rifle shooting, the aim is the same – to direct a projectile at a target with maximum accuracy and consistency.

Good marksmanship relies on simple basic principles – accurate aiming from a steady base, calmness and concentration. Successful archery depends on the archer's body and stance controlling the angle and direction of fire. The arrow is delivered by releasing the drawn string of a bow. Although it has been estimated that 90 per cent of archery is due to the archer's skill and only 10 per cent is due to the equipment, there are strict guidelines for the archer's tools.

Strong bows

The bow can be simple or complicated. It must have the same basic design of a grip, two flexible limbs and a single bowstring. The bow can be a curved longbow, a recurve bow that has a double curve at each end

Alisport



Russell Cheyne/Alisport

Archer's basic principles have hardly changed over the centuries, but the bows and arrows are now made of plastics and Kevlar; targets may soon be made of foam instead of straw.

or a compound bow, using cams and pulleys to give greater force (see NEW TECHNOLOGY, page 43).

The string is usually made of Dacron or Kevlar. Dacron fibre, with up to 12 strands twisted together is long-lasting but tends to stretch slightly. Kevlar is the strong yet lightweight material used in armoured cars and bullet-proof vests.

Kevlar strings do not stretch, but they have a limited life of between

1,000 and 2,000 arrows – a typical day's shooting will be around 150 arrows. Each string needs to be 'shot in' for about 100 arrows, so a Kevlar string will not last much more than a month.

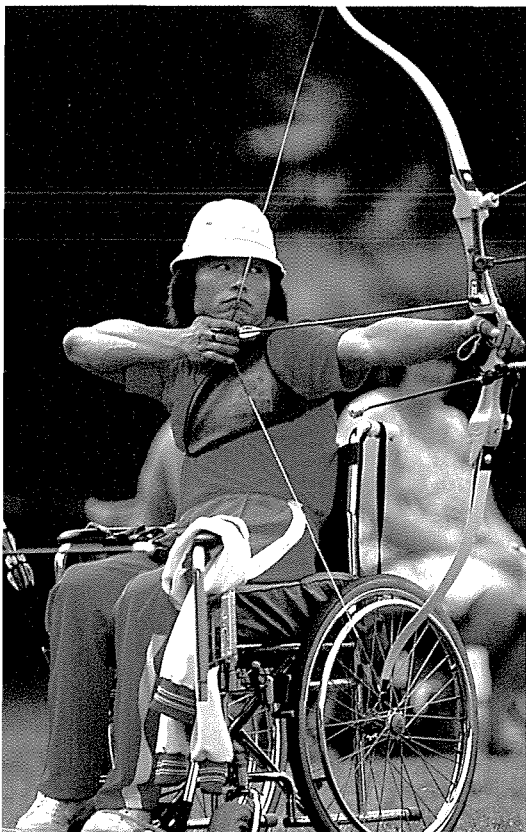
Arrows used to be wooden, but now most are made of tough aluminium alloy, which means they can be straightened if they become bent. The length depends on the size and experience of the archer. Top

LONG-RUNNING ARCHERS

THE OLDEST ARCHERY CONTEST IN THE WORLD IS THE PA-PINGO SHOOT BY THE KILWINNING ARCHERS IN SCOTLAND, WHICH HAS BEEN RUNNING SINCE 1488.



Paul Raymond



that he can shoot with the bow in the same position every time. The essence of good archery is to find the target, and then to keep hitting it by maintaining a consistent draw weight and trajectory time after time.

Shooting

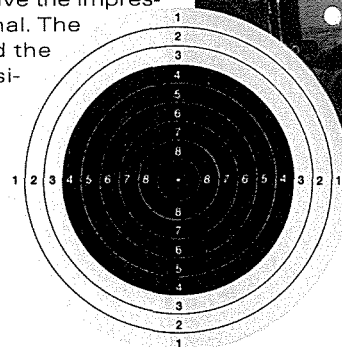
The same principles of accuracy and consistency apply to the shooting of firearms, except that the propellant force of the bullet or pellet will automatically be the same for every shot.

The only occasion lenses or telescopic sights are allowed in shooting is in running game target, an Olympic event that involves shooting at a moving target with ten concentric scoring rings. The target is carried across a 10-metre-wide opening on a trolley designed to give the impression of a running animal. The competitor must hold the rifle in a standing position. He is allowed 30

Wheelchair archers thrive in a sport in which they can compete on equal terms against able-bodied sportsmen and sportswomen.

petitors, who use double-barrelled shotguns loaded with lead-shot cartridges. In this sport, the careful aim of the archer or fixed target shooter is not as important as a trained eye and fast reactions.

Smallbore rifle shooting involves three positions – standing, kneeling and prone. Steady nerves are need-



Smallbore rifle shooting (requires an accurate aim to hit the target (actual size, left). Each rifle butt is tailored to suit the marksman; the glove reduces hand tremors.

archers use carbon arrows, which do not bend. The flights – or 'fletchings' – are usually made of plastic rather than natural feathers.

Loosing arrows

As well as the basic equipment, many archers use stabilizers fitted in front of the bow. They make the bow heavier and lower its centre of gravity, which helps reduce the movement in the hand when the string is 'loosed', or released.

A simple sight is permitted on the bow as long as it has no lens or prism. It may be no more than a ring with a pin in the centre. The archer aligns it with a point on the target, so

shots with the target moving slowly and 30 shots with it moving quickly. This means that as well as calculating the distance, trajectory and velocity of the bullet, he must also allow for sideways movement.

Clay-pigeon shooting

Another Olympic event in which the targets are not fixed is clay-pigeon shooting, derived from live pigeon shooting, which was outlawed in Britain in the 19th Century.

Measuring 110 mm in diameter, clays are launched by mechanical traps in wide arcs above the com-

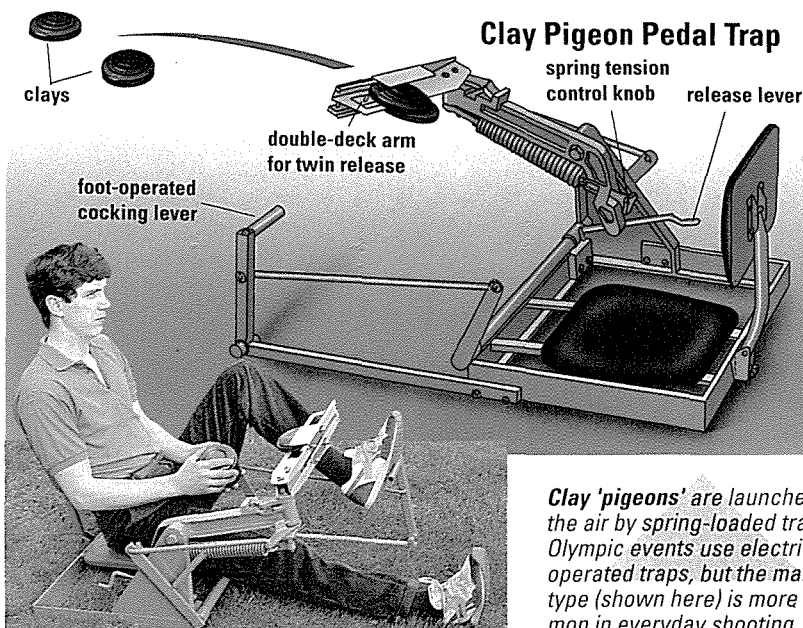
ed to stop the rush of adrenalin that can ruin a marksman's aim in a big competition, so mental relaxation is vital. Keeping as still as possible is essential and the top marksmen have enormous mental and physical control. Concentration must be total to control muscles and maintain a good hold, thus aiming accurately.

Breathing exercises

Many marksmen use special breathing exercises to help them remain virtually motionless while they aim and shoot. Their breathing becomes shallower as the target is lined up, and may stop for up to 8 seconds as they pull the trigger – anything longer would starve the brain of oxygen and cause loss of concentration.

THE MASTER EYE

Most people have one dominant eye that is unconsciously used more when looking at an object. It is this eye that is preferred when looking through a camera or lining up a target. Archers or shooters use this simple test to find out which is their master eye. Hold both index fingers in front of you, 10 cm apart. Keep both eyes open and line up the fingers. Now close the left eye and see if the fingers are still aligned – if they are, then the right eye is dominant. If not, close the right eye and keep the left eye open – if your fingers line up, it means the left eye is dominant. If the fingers don't line up with either eye, but only with both eyes open, then neither eye is the master eye and you may use whichever one you wish.



Clay 'pigeons' are launched into the air by spring-loaded traps. Olympic events use electrically operated traps, but the manual type (shown here) is more common in everyday shooting.

CONDUCTORS

CORROSION

METAL ORES

METALS

METALS ARE INCREDIBLY useful materials. People have been using metals for 8,000 years and yet, even in this age of plastics, they remain an important part of our lives. Metals are resistant to heat, and they conduct electricity – a feat no plastic can achieve.

Claus C Meyer/Colorific



In the hostile environment of a steel works, iron is combined with carbon to make the harder alloy steel.

Metals generally have a shiny appearance, or metallic lustre, and they can usually be fashioned into thin sheets by hammering – a property known as malleability. Some metals are described as being ductile, which means that they can be drawn out into thin wires.

As well as conducting electricity, metals are good conductors of heat. They all behave chemically in a similar way, too. When metals react with oxygen they form substances known as bases, or alkalis. A base is a chemical that reacts with an acid to form a salt, which is a combination of a metal and one or more non-metals;

examples include common salt, or sodium chloride, lead sulphate and potassium nitrate.

Semi-metals

Of the 92 naturally occurring elements, 69 are classed as metals, but there are also five semi-metals – elements that sometimes behave like metals and sometimes like non-metals. These are boron, germanium, arsenic, selenium and tellurium.

The properties of metals differ from one to another and this makes them useful for different purposes. For example, the best conductors of heat and electricity are silver and copper,

Metals have many uses. These huge rolls of sheet aluminium will be made into parts for cars, ships and planes – and into foil to wrap the Christmas turkey.

but, as silver is less widely available, it is copper that is generally used in electricity cables and heating systems. Iron is very common and also very easy to work. This and the fact that it can be turned into the much harder form known as steel, makes it the world's most commonly used metal. Most metals are solid at normal temperatures, but mercury is a liquid. It expands noticeably when

Tony Stone Photo Library



Gold bars are made by heating gold in a furnace until it melts at 1064°C. The molten metal is poured into moulds where it cools and solidifies.

heated and is therefore mainly used in thermometers.

Some metals react with other chemicals very easily. Sodium and potassium, for example, react by fizzing violently on contact with water and are never found in the pure state in nature. Other metals react more slowly; iron, for example, forms iron oxide (rust) when exposed to air and water, and copper eventually becomes covered in a green film – a type of copper carbonate.

Gold and silver

Among the metals that are least susceptible to corrosion in air are lead and aluminium. Lead is a rather soft, dense metal and, in its pure form, is limited to such things as roofing and car battery plates. Aluminium, on the other hand, is a much harder metal that is very easy to work. It therefore

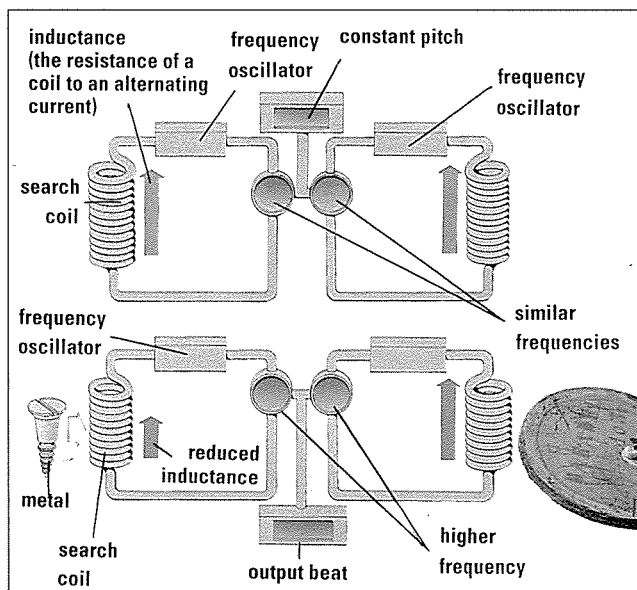
has a very wide range of uses including car bodies, aircraft frames, long-distance power transmission lines, window frames, saucepans and kitchen foil. The least reactive metals are silver and gold, which, being rare, are used to make jewellery.

Mineral ores

Some metals occur in the pure, or native, state in nature. Most gold, for example, is obtained in this form, and in a few places native silver and copper can be found. All other metals are obtained in the form of mineral ores. These have to be dug up and then treated to obtain the pure metals.

A metal ore is generally extracted from the ground by mining, either on the surface or deep underground. The details of the process in which a metal is then extracted from the material that is mined varies from metal

Tony Stone Photo Library



A metal detector works by comparing the frequencies in two circuits (left). When one coil comes near metal, the listener hears a series of pulses

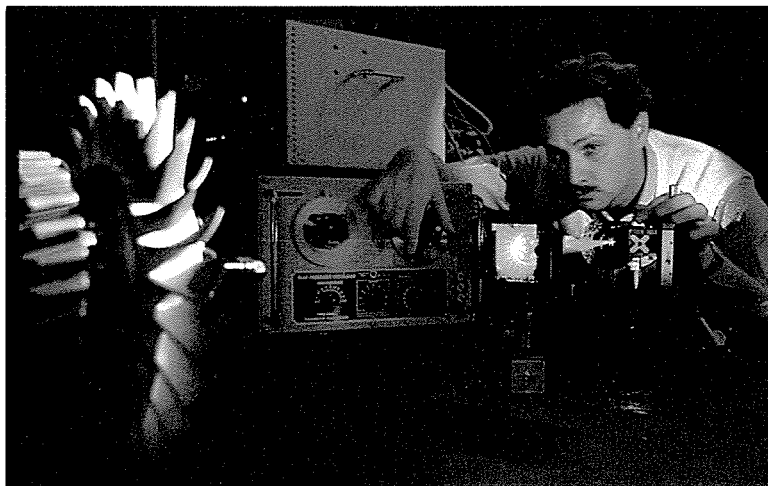


Cory/Jerrican

Holograms are used to test metal helicopter rotors.

Once the hologram has been made the real rotor can be subjected to severe vibrations, then it can be compared with the hologram in laser light so that minute distortions can be detected.

Philippe Plailly/Science Photo Library



to metal. Usually, the ore is first separated from the gangue – unwanted earth and rock. Some metal ores, such as those of iron, lead, tin and copper are then smelted (heated to a high temperature in a furnace with other chemicals) to release the metal. Aluminium, on the other hand, is extracted by a chemical process to produce a chemical known as alumi-

MIXING METALS

An alloy is formed when metals are melted together. One familiar alloy is stainless steel, which is steel mixed with chromium and nickel. The chromium at the surface reacts with oxygen in the air to form a thin layer that prevents corrosion. Adding manganese to steel makes it tougher, and molybdenum and tungsten help steel tools stay sharp.

Copper and zinc form brass, which is more resistant to corrosion. Bronze is an alloy of copper and tin; it melts at a lower temperature and is easier to cast. Pewter is an alloy of lead with antimony and copper, and dentist's amalgam for fillings is composed of mercury and copper. Sterling silver contains 7.5 per cent copper while 18-carat gold contains 25 per cent silver and copper.

Just amazing!

STEEL BAND
700 MILLION TONNES OF STEEL IS PRODUCED WORLDWIDE EACH YEAR -- ENOUGH TO MAKE A 1-MM-THICK WIRE THAT WOULD WRAP ROUND THE WORLD OVER 28 MILLION TIMES.

Paul Raymonde

na, which is then electrolysed – that is, electricity is passed through it – to produce pure aluminium.

Some metals are more dense than others, which means that the matter they contain is concentrated into a smaller space. For example, lead is very dense, which is why a small piece is so much heavier than a similarly sized piece of aluminium.

MATERIAL MATTERS

ATOMIC NUMBERS
THE BIG BANG
RADIO ISOTOPES

EVERYTHING AROUND US, every material or substance that we can see or feel, is made of what scientists call matter. And all matter is made up of tiny particles called atoms. There are a number of different kinds of atoms. However, when all the atoms in a substance are exactly the same, the substance is known as an element.

Scientists know of over 100 different elements. Of these 92 occur naturally in the world about us. Examples include hydrogen, helium, oxygen, carbon, iron, silver and lead. Each element is known by a name given to it when it was first discovered. Each element is also distinguished by a number, called its *atomic number* – defined by the number of protons in the atom. Hydrogen is thus 1, helium 2 and so on.

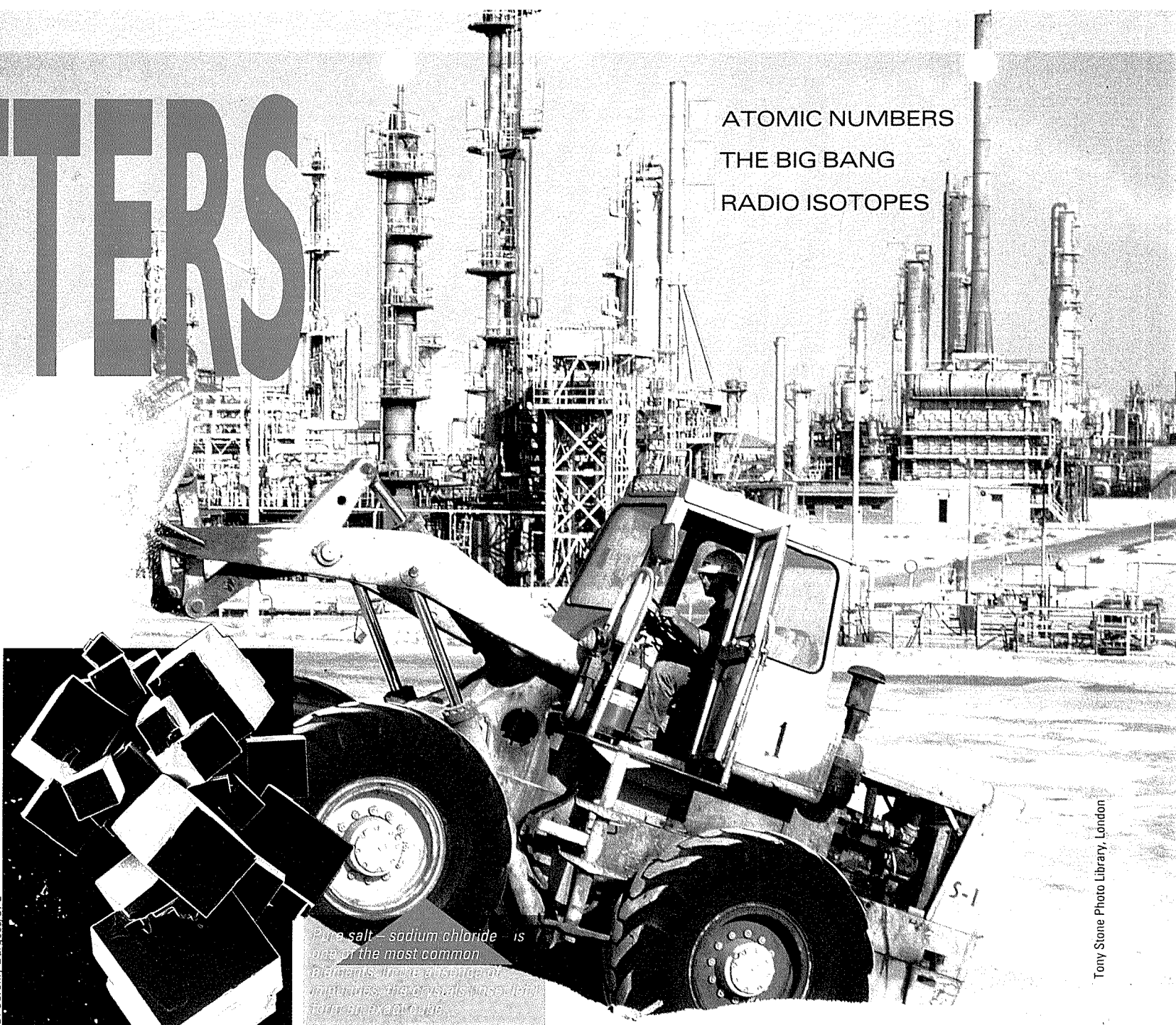
Artificial elements

All the known elements can be arranged in a table, known as the Periodic Table (see Dataquest, Issue 39), in which the horizontal rows show the elements in the order of increasing atomic number. The vertical

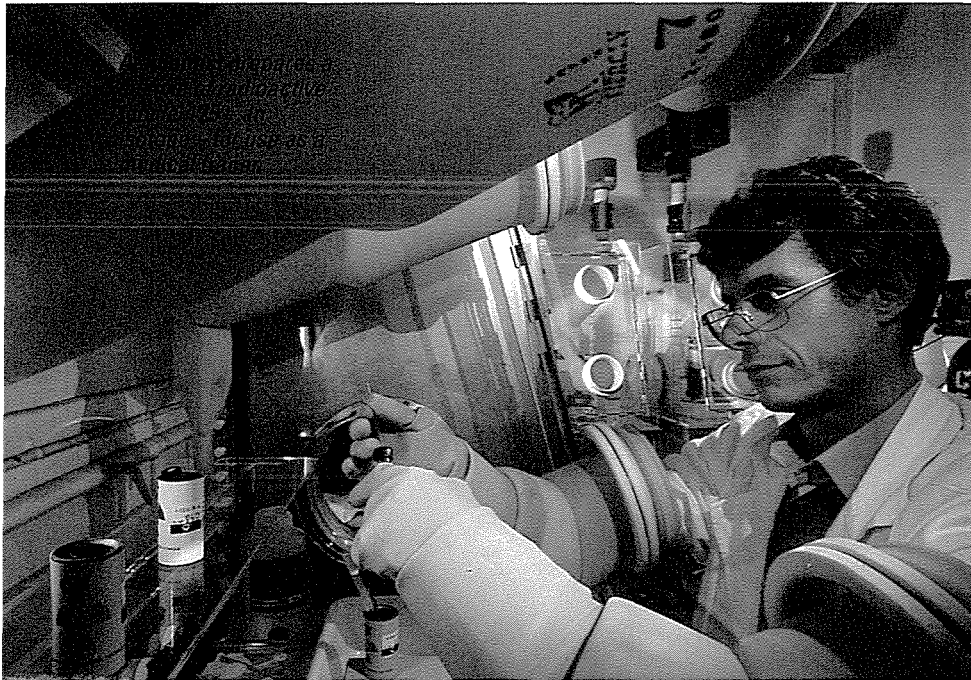
Dr Jeremy Burgess/SPL



Pure salt – sodium chloride – is one of the most common elements. In the absence of impurities, the crystals usually form an exact cube.



Tony Stone Photo Library, London



Philippe Plailly/Science Photo Library

columns, known as periods, contain elements that have similar chemical characteristics.

Elements with atomic numbers of over 92 do not occur in nature, but they can be made artificially. The elements neptunium (atomic number 93) and plutonium (94), for example, are formed when uranium is bombarded with slow-moving neutrons in a nuclear reactor. Americium (95) can be made by

occur naturally were also created. But they were created by the events that formed the universe. The simplest and smallest atoms were created first, during the huge explosion known as the Big Bang. One tenth of a second after the Big Bang took place the first protons had been formed. Four minutes later these protons had interacted to form the lightest elements, hydrogen, helium, and lithium. The hydrogen

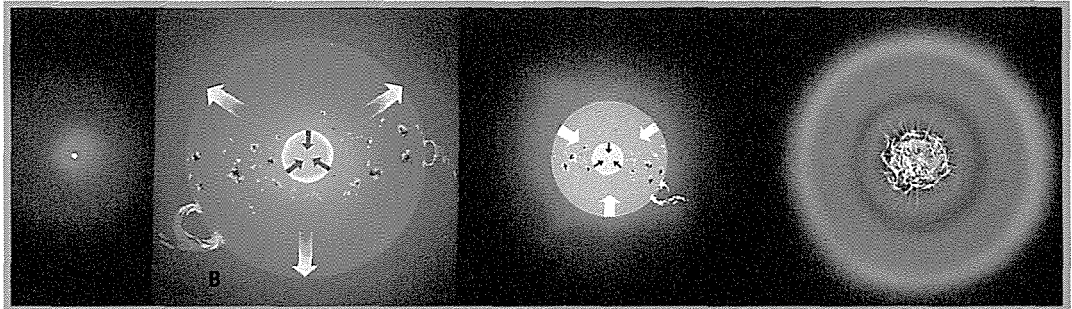
the same element from each other they are normally known by their mass numbers, that is the total number of protons and neutrons in each atom. Thus normal hydrogen is hydrogen-1, deuterium is hydrogen-2 and tritium is hydrogen-3. In practice most elements exist as two or more isotopes, and so their atomic weights are seldom nice round figures. Iron, for example, has four main isotopes, iron-54, iron-56, iron-57 and iron-58. The normal atomic weight of iron is 55.84, which

ROCK WEAR

Asbestos is the name given to the fibrous forms of several kinds of rock. Strictly, asbestos is the fibrous form of actinolite. Most commercial asbestos, however, comes from another mineral – chrysotile. Its fibres are short but fine and strong; 1 kg of chrysotile can produce 88,700 metres of asbestos thread.

Being made of rock, asbestos does not burn, and its melting point is very high. And because it is fibrous, it is easy to weave into fabrics and compress into flat panels in order to create fire-resistant materials. Unfortunately, if people breathe in the tiny fibres they can develop a disease known as asbestosis. The sharp fibres irritate and damage the delicate lining of the lung, and may also pierce the lung and damage the outer lining. Sufferers often develop lung cancer.

Supernovae, the violent explosions of stars, are responsible for distributing all the natural elements. A blue star (A), powered by hydrogen fusion, expands to form a red giant (B), which collapses (C), then rebounds (D) – blowing the star apart.



Sally Bensusen/Science Photo Library

bombarding plutonium with neutrons, and curium (96) is made by bombarding plutonium with the nuclei of helium atoms. This has to be done at very high speed and an accelerator is used to get the helium nuclei moving fast enough.

Super-heavy elements

Scientists have made elements with atomic numbers of up to 108 and in 1987 a group of Russian scientists claimed to have made one with an atomic weight of 110. These elements exist for only a few milliseconds, before they rapidly decay into elements with lower atomic numbers. However, some scientists suggest that if so-called super-heavy elements, with atomic numbers of over 114, could be made, they might perhaps be more stable.

Of course, all of the elements that

and helium then began to form stars, inside which heavier elements began to form. Helium nuclei fused to form beryllium, and beryllium nuclei fused with helium nuclei to form carbon – the element that is a vital part of every living thing on Earth. Next carbon and helium nuclei fused to form oxygen, and so on until all the elements that we know were formed. Some of the early stars blew themselves apart in explosions, known as supernovae, scattering the newly-formed elements far and wide. Over many millions of years the elements were spread throughout the universe.

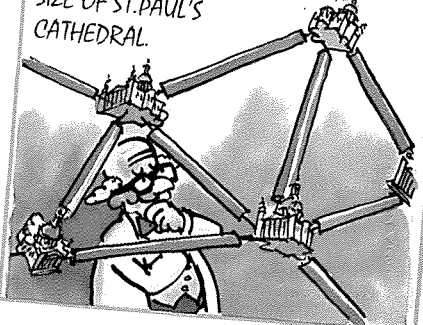
Mass numbers

Different forms of the same element – that is, atoms with the same number of protons, but different numbers of neutrons – are known as isotopes. To distinguish isotopes of

Just amazing!

A NUCLEAR MARBLE

THE ELECTRON/NEUTRON-CONTAINING NUCLEUS OF AN ATOM IS THE SMALLEST PART. IF IT WAS AS BIG AS A MARBLE, THE WHOLE ATOM WOULD BE THE SIZE OF ST. PAUL'S CATHEDRAL.



Paul Raymond

reflects the relative abundance of these isotopes.

In most cases isotopes are unimportant to us. A few, however, are useful. Deuterium, for example, is used in the form of deuterium oxide, or heavy water. Heavy water (see PLANET EARTH page 69) has the property of being able to slow down moving neutrons more easily than normal water. It is therefore used in some nuclear generating plants as a combined reactor coolant and moderator (neutron slower).

Among the most useful isotopes are those that are radioactive. These are unstable isotopes that naturally

Petroleum is a naturally occurring mixture of hydrocarbons, often found with traces of sulphur and vanadium.

Although widespread in the Earth's crust, oil companies have increasingly had to search and drill – from rigs such as the Claymore-A in the North Sea – beneath the sea.

Radiation from the nuclear accident at Chernobyl, Ukraine in 1986 sent farmers out with Geiger counters to check their crops.

break down, or decay, into other elements. They do this by giving out radiation in the form of sub-atomic particles – either an alpha particle (two protons and two neutrons) or a beta particle (an electron moving at high speed). Sometimes gamma rays are given out as well. Alpha particles, beta particles and gamma rays can be detected using special equipment, such as a Geiger counter. So radioactive isotopes, or radioisotopes, make excellent tracer

The modern car consists of a vast 'stew' of chemical elements. The most commonly occurring is carbon – found in just over a fifth of the materials.

materials. If a radioisotope is fed into a mechanical, chemical or biological system, its path through the system is easy to follow.

Radioisotopes are now widely used in medicine, in industry and in scientific research. For example, iodine-131 can be injected into a patient's body to test how well the thyroid gland is working. Iodine normally accumulates in the thyroid gland and by detecting how much radioactive iodine accumulates, doctors can find out if the gland is underactive, overactive or working normally. Other isotopes used in medicine include strontium-85, technetium-99 and indium-111.

Paul Williams

Ceramics

15 engine components - ceramics (Al₂O₃)

16 disc brakes - asbestos (Mg, O, Si, H)

Elements Table

Al	aluminium
Be	beryllium
C	carbon
Cl	chlorine
Cu	copper
Fe	iron
H	hydrogen
K	potassium
Mg	magnesium
Mo	molybdenum
N	nitrogen
Ni	nickel
O	oxygen
Pb	lead
Si	sodium
S	sulphur
Te	tellurium
V	vanadium
W	tungsten
Zi	zinc

Plastics

- 1 carpet - nylon (C, H, N)
- 2 interior trim - PVC (C, H, Cl)
also PVC - coated fabrics
- 3 tail lamp covers - acrylic (C, H)
- 4 fuel tank - high-density polyethylene (C, H)
- 5 fascia panel - ABS polypropylene (C, H)
- 6 body panels - glass reinforced plastic (C, H, Si, O)
- 7 seats - polyurethane (C, H) + other plastics
- 8 bumper - ABS (C, H, N) polycarbonate (C, H, O)
polypropylene (C, H)

Minerals

- 12 distributor head - mica (Mg, Al, Si, K, O, H)
- 13 distributor - talc (Mg, Si, O, H)

Metals

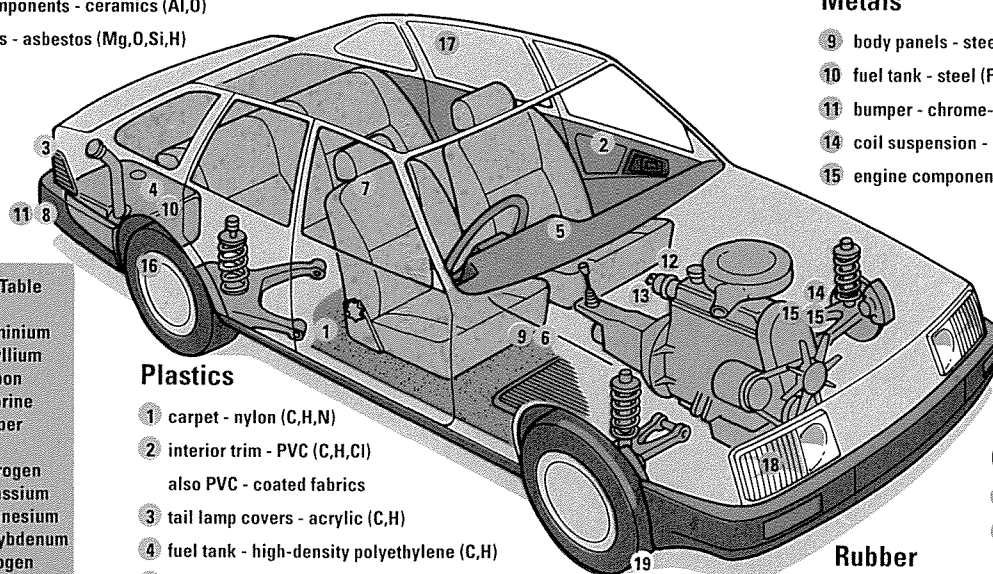
- 9 body panels - steel (Fe, C)
- 10 fuel tank - steel (Fe, C)
- 11 bumper - chrome-plated steel (Fe, Cu)
- 14 coil suspension - steel vanadium alloy (Fe, C, V)
- 15 engine components - aluminium (Al)
beryllium (Be)
lead (Pb)
molybdenum (Mo)
nickel (Ni)
steel (Fe, C, W)
tellurium (Te)
zinc (Zi)

Glass

- 17 windows - glass (Si, O)
- 18 headlamps - glass (Si, O)

Rubber

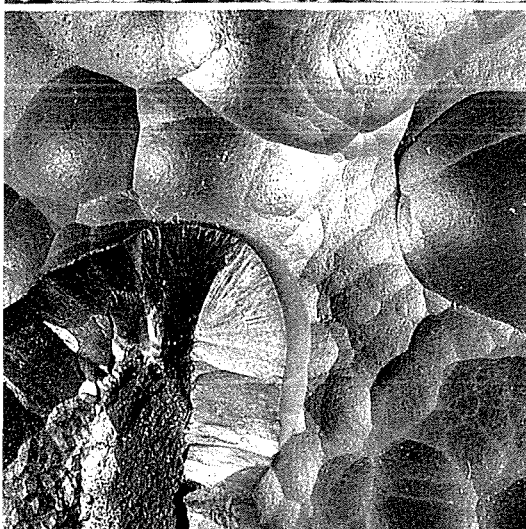
- 19 tyres - vulcanized rubber (C, H, S)



Richard Folwell/Science Photo Library

Gamma/Frank Spooner Pictures

VIEW MINERAL WEALTH

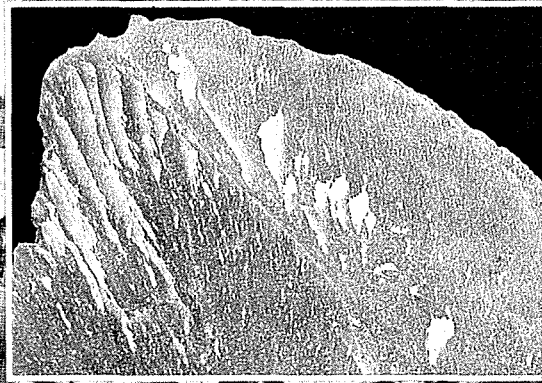


Opal is one of the most beautiful of gemstones. It comes in many shades, but the most common is orange-yellow. It is a type of silica crystal, highly prized as a gemstone. It is often found in a porous, cellular structure, and is extremely hard.

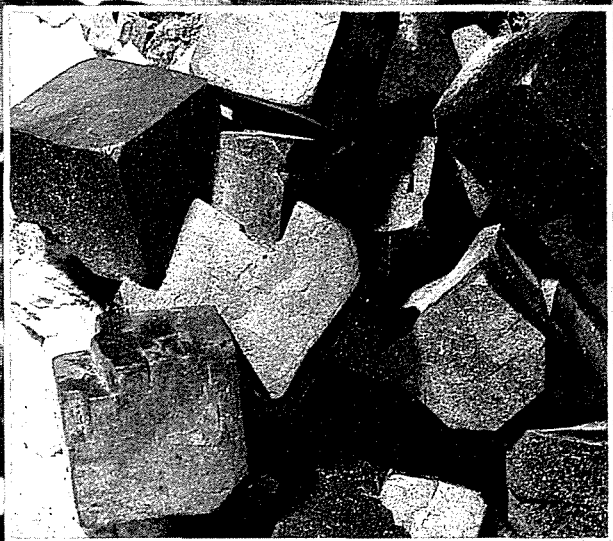
A nodular (grape-like) mass of haematite - a red or black mineral consisting of iron ore. It is the most common iron ore, and is weakly magnetic.



Talc is a soft, greasy mineral containing magnesium silicate. Apart from the popular talcum powder, it is used in cosmetics, paint, and as a lubricant.

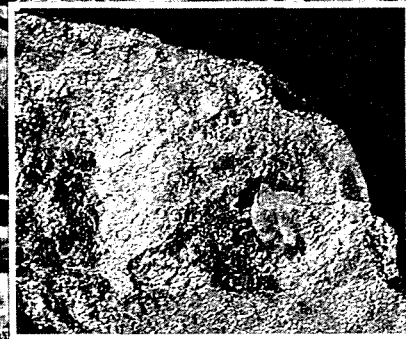


Gunpowder crystals, or saltpetre, are used in matches, gunpowder, and sulphuric acid.



Lead sulphide or galena is the most common ore of lead. The mineral is found in clusters of hexahedral (six-sided) crystals.

Quartz is a widespread mineral that is a major component of sands and sandstones.



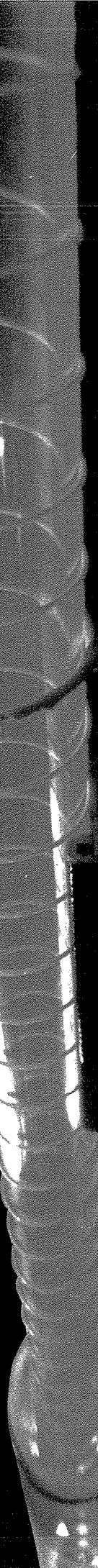
Copper pyrites is an abundant copper ore. One of the first metals to have been used by humans, it is also one of the strongest pure metals.

BOMB AIMING

RANGE FINDING

SILENT WEAPON

BEAMS IN BATTLE



Huge lasers were built as part of the Star Wars programme. The aim was to launch them into space on satellites, where they were supposed to destroy incoming ballistic missiles.

LASER BEAMS HAVE ALWAYS conjured up the science fiction image of the death ray. But it is only very recently that they have had any real military application.

Modern armies now use lasers as target designators usually known as laser target markers. When forward air controllers called in aircraft to provide close support to troops on the battlefield they often used to risk bombing their own men. A pilot flying perhaps as low as 100 ft. at 400 knots, who is being shot at, could easily make fatal mistakes.

The task of the forward air controller - the man who calls in air support - is made much easier by a laser target marker. Now all he has to

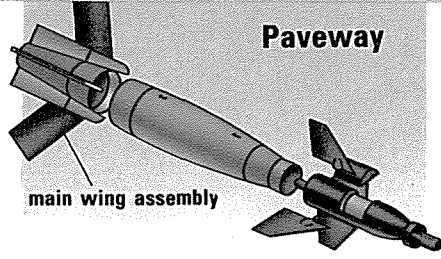
do is get himself into a position on the ground where there is a direct line of sight between him and the target. He shines the laser beam directly on to the target. When the air support comes in, the pilot drops his bombs into the envelope of energy reflected from the target. Sensors in the nose of the bomb detect the source of the energy and home in on the target.

Easy accuracy

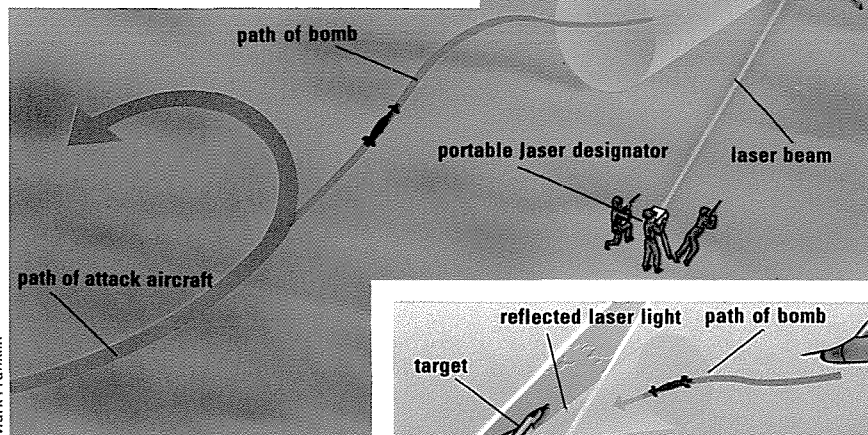
The bomb has no propulsion system, so its trajectory can only be altered slightly. But laser target designation means that pinpoint accuracy is no longer required. The pilot only has to drop his bomb in the right area - an enormous advantage in battle.

Where a forward air controller

Alexander Isayas/Science Photo Library

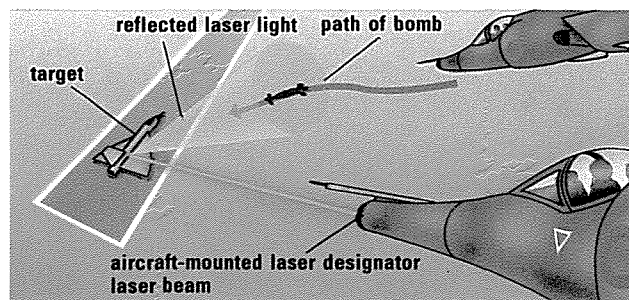


Paveway



Ferranti/TRH Pictures

The guided bomb Paveway has small steerable wings on its nose cone (top) which guide the bomb down the cone of laser light reflected from the target.



The laser designator must be in line of sight of the target. The forward air controller simply points the laser beam at the target. A bomb dropped in the general vicinity will then be guided home. Laser designators can also be carried in the nose of an accompanying aircraft (below left).

cannot get within line of sight of the target, another aircraft with a laser designator mounted on it can pinpoint the target while a bomber delivers the high explosive.

Artillery forward observation officers also use laser target markers to guide 'smart' shells. This dramatically increases the effectiveness of artillery.

On target

In aircraft, laser equipment is also used to provide accurate target ranges. Bombs may be dropped automatically with remarkable precision, after a computer has made allowances for even minute variables such as wind speed and direction.

On land, too, lasers are used to gauge distances accurately. Before a



GEC Ferranti

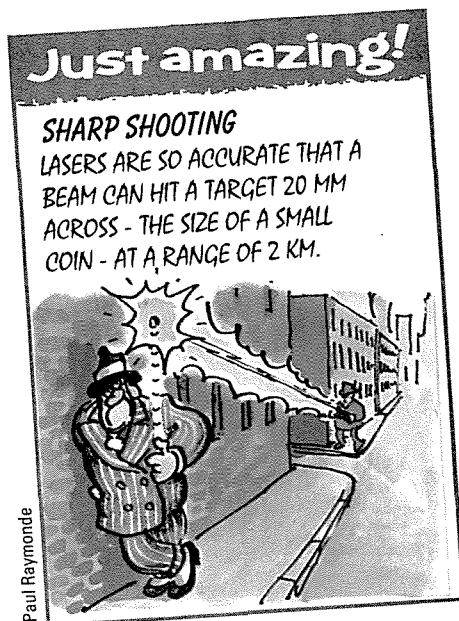
Although British ships already had a number of anti-aircraft defence systems, including missiles and rapid-firing heavy machine guns, it was considered unwise to use such hostile armaments in sensitive situations.

Laser weapons were first fitted in 1986 to ships serving in the Armilla patrol in the Arabian Gulf where Britain played a key role in escorting merchant ships at risk from attack during the Iran/Iraq war. Each of the three navy ships serving in the Gulf had two laser weapons. More recently the devices have been fitted to ships serving in the Falklands.

Blinding light

The laser weapon sends out a powerful beam of light that at a range of 1 kilometre can temporarily blind an enemy pilot. This will force the pilot to abandon his bombing run or, if he manages to remain on course, to drop his bombs wide of the target. The system is not powerful enough to cause permanent damage to the eyesight and is designed to be used in situations where blowing an attacking aircraft from the skies is liable to provoke further hostilities.

In the early 1990s, following the break up of the Soviet Union and reduced threat of nuclear war laser research was directed towards developing a global defence system against the impact of asteroids from space.



Paul Raymond

-  BUTTON CELLS
-  SOLAR CELLS
-  ELECTRIC CARS

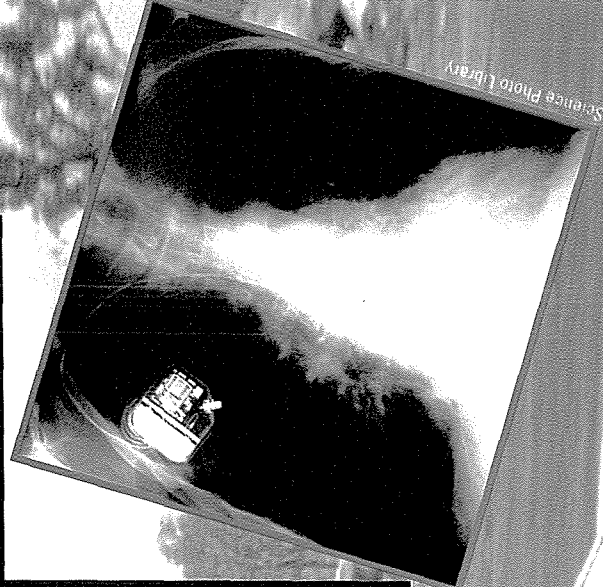
POWER PACKS

FROM THE TINY CELLS that run hearing aids and electronic watches, to the bulky batteries used to start cars, portable power is available in a variety of forms to serve every imaginable modern need.

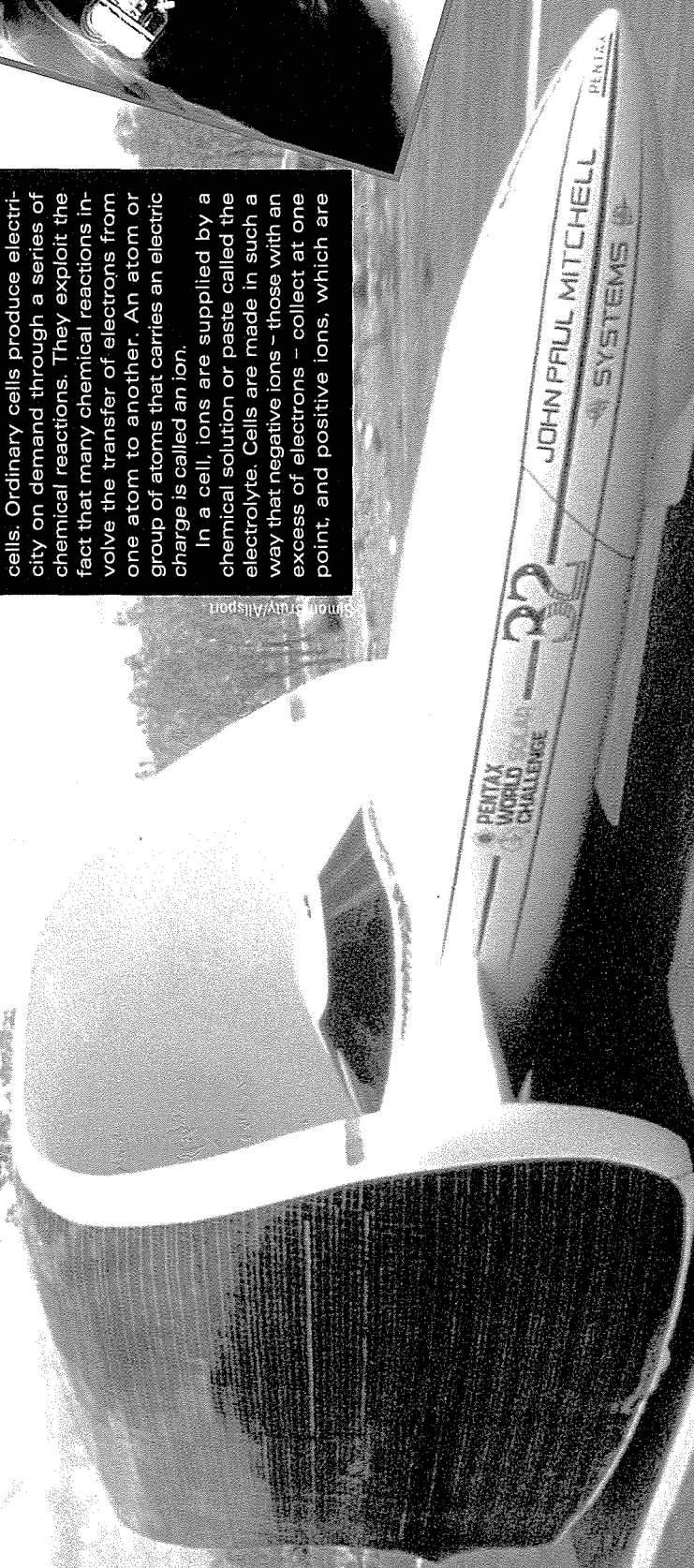
A battery consists of one or more cells. Ordinary cells produce electricity on demand through a series of chemical reactions. They exploit the fact that many chemical reactions involve the transfer of electrons from one atom to another. An atom or group of atoms that carries an electric charge is called an ion.

In a cell, ions are supplied by a chemical solution or paste called the electrolyte. Cells are made in such a way that negative ions - those with an excess of electrons - collect at one point, and positive ions, which are

An array of solar cells can produce enough energy from sunlight to power an electric car (below left). The battery in a heart pacemaker (below) can last for up to ten years.



Science Photo Library



Simon Crilly/Allsport



Battery-operated tools are convenient to use as there are no trailing mains leads. After use, this electronic screwdriver is attached to a wall-mounted mains unit to ensure that its batteries are fully charged when it is next required.

ducting paste of ammonium chloride, zinc chloride, manganese dioxide and carbon particles.

In a cylindrically-shaped cell, the carbon rod, capped with steel, emerges as the positive terminal at the top. The bottom of the zinc casing, or a thin steel covering directly in contact with it, acts as the battery's negative terminal.

Increased output

A cell of this kind, whatever its size, will supply 1.5 volts. Making it bigger simply increases the maximum current that the cell can supply. Higher voltages are obtained by combining several cells in one battery. For instance, a 9-volt battery contains six 1.5-volt cells joined together in series, a 6-volt, four and so on.

Zinc-carbon batteries have the advantage of being cheap. But more expensive types of

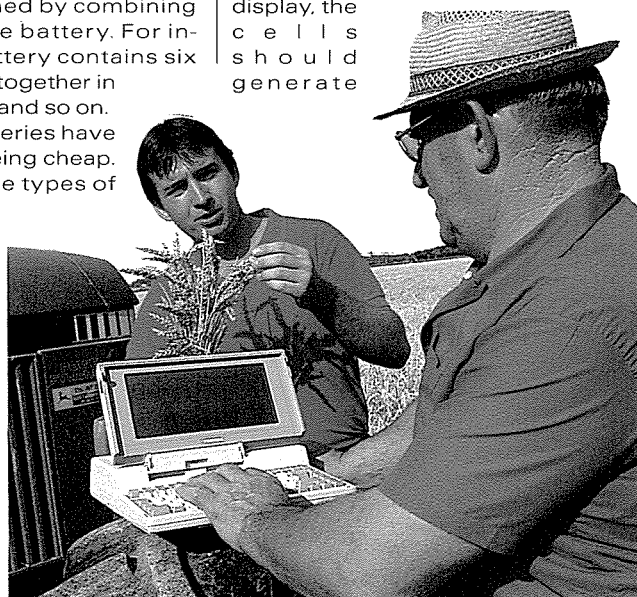
rent flows through the battery in the opposite direction to normal. As a result, the chemicals in the electrolyte are once again returned to their original state, so the battery can once again supply current.

Solar cells

Some equipment runs on cells that last a lifetime but never need charging. Many pocket calculators, for example, are powered by solar cells. These convert the energy of daylight, or artificial light, into electricity.

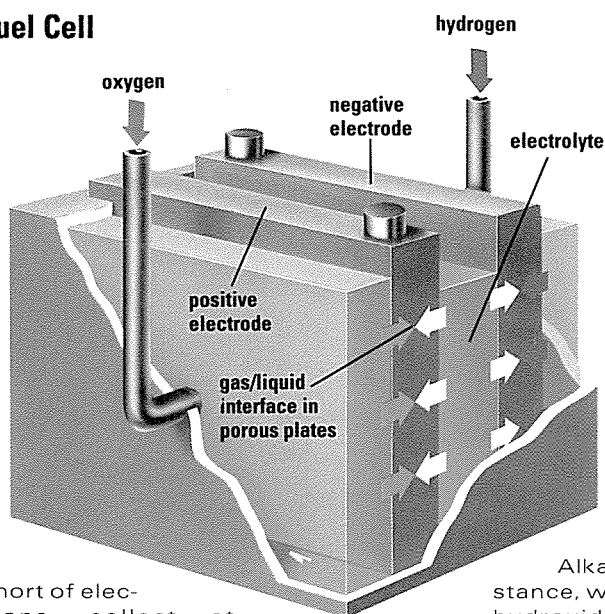
Wherever there is enough light to see the numbers on the calculator's display, the cells should generate

Portable lap-top computers have revolutionized many fields of work. Data can now be entered directly, wherever it is collected.



Ivaldi/Jerrican

Fuel Cell



short of electrons, collect at another point. These collection points, called electrodes, are in contact with the electrolyte. A terminal on each electrode allows the cell to be connected to a circuit. When this is done, a stream of electrons flows from the negative terminal to the positive. This flow of electrons is an electric current.

Standard cells

The most common type of cell is the zinc-carbon type. A carbon rod in the middle of the battery acts as the positive electrode, while an outer casing of zinc serves the dual purpose of container and negative electrode. Between the two electrodes is the electrolyte - in this case, a moist, con-

The fuel cell may power cars of the future. In the type of fuel cell shown here, hydrogen and oxygen gases pass through the porous electrodes, combine with the electrolyte, and produce electricity in the process.

sufficient power to operate the electronic circuits inside.

Even experimental cars have been powered by solar cells, but a more promising power source for future electric vehicles is the fuel cell. This produces electricity by combining hydrogen and oxygen gases. Unlike today's petrol-powered vehicles, a car running on a fuel cell would not pollute the environment - the only waste product would be water.

battery give better performance.

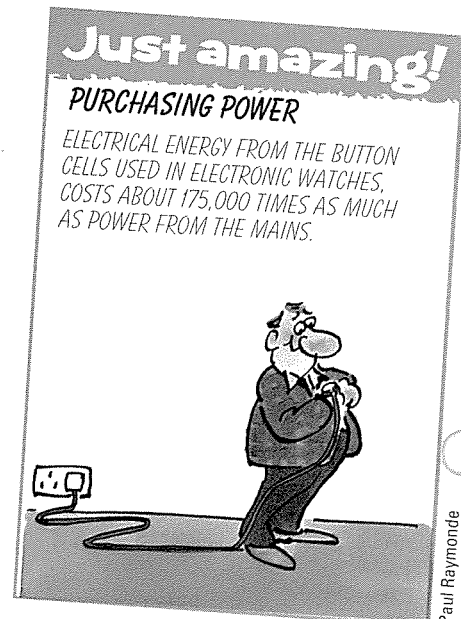
Alkaline batteries, for instance, which use potassium hydroxide as the electrolyte, last longer. They also work more efficiently at low temperatures.

The miniature button cells used in electronic watches, hearing aids and some calculators and cameras employ layers of zinc powder and either mercury oxide or silver oxide as electrodes, with potassium hydroxide in between as the electrolyte.

Rechargeable cells

Most batteries have to be thrown away when they run down. But a nickel-cadmium battery, though marginally more expensive, can be charged up very cheaply over and over again. This is done by inserting it in a mains-supplied recharging unit.

During recharging, an electric cur-



Paul Raymond

MICROWAVES



RADIO WAVES WITH A VERY short wavelength - or microwaves - were largely ignored by scientists until about 50 years ago. Yet today, they are used for diverse tasks from studying the origin of the Universe to heating up pizza in seconds.

Microwaves are used in radar, satellite communications, atomic

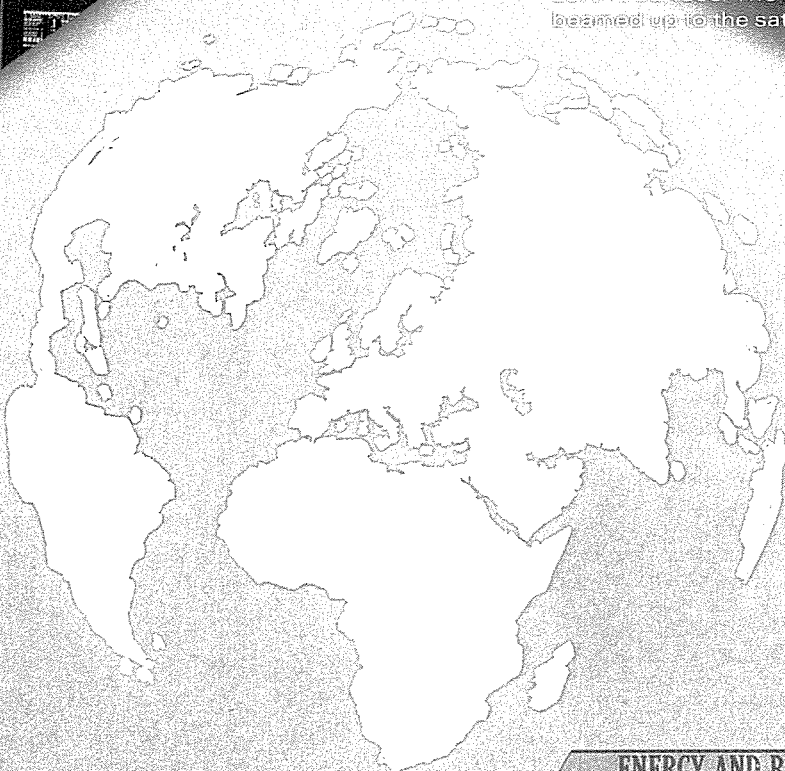
clocks and cookers. Microwave energy is a type of electrical energy that can be transmitted through Space.

Communications

Microwave signals carrying television, telephone and computer data can be relayed by an orbiting satellite between two points on the Earth's surface. The microwaves are beamed up to the satellite - usually at

An Earth-orbiting satellite can at any one time, handle two TV channels, 12,000 telephone conversations and computer data via microwaves.

Communications between spacecraft and ground control use microwaves because of their ability to penetrate the Earth's atmosphere. One user is the European Space Agency's Operation Centre (above) in Darmstadt, Germany.



a fixed position in the sky – from an Earth station – a large dish-shaped transmitter. Signals are boosted and shifted to a different frequency before being transmitted to a different part of the Earth's surface. The signals are picked up, by another large dish antenna for distribution to homes and workplaces, or, if the signals are powerful enough, they may be collected directly by small rooftop dishes.

COSMIC WAVES



NASA

In 1965, American scientists Arno Penzias and Robert Wilson were studying natural sources of microwaves in Space that cause interference in telephone lines. They discovered a weak microwave 'glow' at a wavelength of 7.35 cm, coming from all parts of the sky. This cosmic microwave background is now believed to be the remains of the colossal explosion, or Big Bang, which formed the Universe.

A spacecraft called COBE (Cosmic Background Explorer) was launched in 1989 to carry out a two year study of the microwave background from Earth orbit. Two of COBE's detectors were chilled by liquid helium to within 2° of absolute zero so that they did not radiate more microwaves than they were trying to detect. These instruments were so sensitive that they could detect the power received by a postage stamp in London from a light bulb in Liverpool. From tiny variations in the cosmic background, astronomers hope to determine when and how the first galaxies formed.

On ground level, microwave links connect electronic news gathering (ENG) teams with their central television station. This avoids interference with longer radio waves that broadcast television and radio.

Microwaves for long-distance communications are generated by a

The Sun emits energy as waves of electromagnetic radiation. The longer their wavelength the shorter their frequency. Microwaves bridge the gap between normal radio waves and infra-red (heat waves). Radio frequencies range from EHF (extra high frequency) to VLF (very low frequency).



A communications satellite is born – launched in Space from the cargo bay of the American Space Shuttle Discovery, in 1985, to take up a fixed position in orbit around the Earth.

NASA Science Photo Library

device called a maser. Just as lasers give out bright, pure beams of light, so masers produce intense, narrow beams of microwaves at a single frequency. Masers work by energizing the molecules of certain crystals, liquids or gases, causing them to give off a flood of photons.

Masers

In an ammonia maser, for instance, excited molecules vibrate with a natural frequency of 24,000 million times per second. Introducing a weak input beam of exactly this frequency triggers a chain reaction in which large numbers of the excited molecules drop to a low energy state – in the process giving off an intense beam of 24,000 MHz (1.25 cm) microwaves. Because of this precision, ammonia masers are used as a frequency or time standard and form the basis of atomic clocks.

Radar

Being highly sensitive, masers are also used to amplify or detect electromagnetic radiation – including very weak radio signals in Space (see Cos-

Fixed aerials used for amplifying and relaying microwave signals are called repeaters. These must be spaced within line of sight, across country because microwaves are unable to pass through obstructions, such as hills or buildings.



mic waves box) and are used in long-distance radar systems.

Radar (Radio Detection And Ranging) bounces radio waves off distant objects. The radio waves are sent out in a sweeping, focused beam and the returning signal is detected by an antenna. They are used to calculate the distance, heading and speed of, for example, an aircraft.

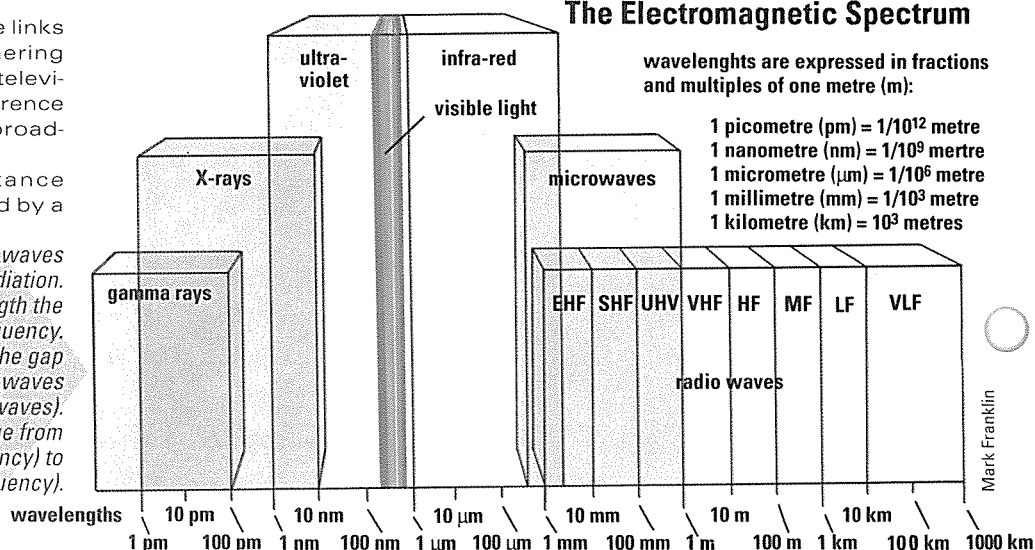
Ordinary radio waves are too long to be able to 'see' clearly an object as

Telefocus

The Electromagnetic Spectrum

wavelengths are expressed in fractions and multiples of one metre (m):

- 1 picometre (pm) = $1/10^{12}$ metre
- 1 nanometre (nm) = $1/10^9$ metre
- 1 micrometre (μm) = $1/10^6$ metre
- 1 millimetre (mm) = $1/10^3$ metres
- 1 kilometre (km) = 10^3 metres



Mark Franklin

ponent of a microwave cooker used to cook and heat food and also thaw it from frozen. Microwaves themselves contain no heat. It is their effect on water molecules that in turn heats food (see box p 134).

Core temperature

Microwaves are reflected by metal, are partly absorbed by water and pass straight through non-metallic substances such as plastic. All inner surfaces of the microwave cooker are metallic to reflect microwaves towards the food placed inside.

Because they are absorbed by water molecules, microwaves penetrate food to a depth of only 5 cm. The centre of a large piece of meat is cooked by heat conducted from the outside – just as your hands heat up when you rub them together. Tests on pre-cooked meals have shown microwave cooking to be less effective with salty food. Salt contains ions (charged atoms or groups of atoms) that flow under the influence of the

James Stevenson/Science Photo Library



Radar equipment onboard the H M S Yarmouth alerts the ship to the range and bearing of the coastline and location of other vessels in the surrounding area.

James Nettis/Science Photo Library



Radar consoles in the control room at Philadelphia International Airport, USA, show aircraft flight maps and warn of weather problems. Radar, in conjunction with advanced instrument landing systems, can land aircraft fully automatically if required.

A tornado developing in Northern Oklahoma, USA, shows up on a radar display screen as a brown/yellow peninsular area to the left of this picture.

show as yellow or green. If the radar data indicates a thunderstorm ahead, the pilot will call ground control for permission to chart a course around it.

The magnetron

Very long-distance radar uses masers to generate microwave signals but most radar systems employ a simple device called a magnetron. Inside a magnetron, a negatively charged electrode, in the centre of a vacuum-filled space, acts as a source of electrons.

The electrons (tiny negative charges), are drawn across the airless gap by the positive charge on a surrounding electrode. At the same time, the electrons are influenced by a powerful magnetic field. This makes the electrons spiral rapidly as they move outwards, causing them to give off microwaves. The shape of the gap and the strength of the magnetic field determine the precise frequency of the microwaves given off.

A magnetron is also the main com-

electric field of microwave radiation. This stops the microwaves penetrating food sufficiently to heat it to a temperature that kills the organisms that can cause food poisoning.

Microwaves may be the key to long term food preservation. Food could be effectively sterilized by heat-

Just amazing!

TIME-KEEPING

THE WORLD'S MOST ACCURATE CLOCKS ARE BASED ON TWO HYDROGEN MASERS AT THE US NAVAL RESEARCH CENTRE IN WASHINGTON, USA. THEY KEEP TIME TO WITHIN 1 SECOND IN 700,000 YEARS.



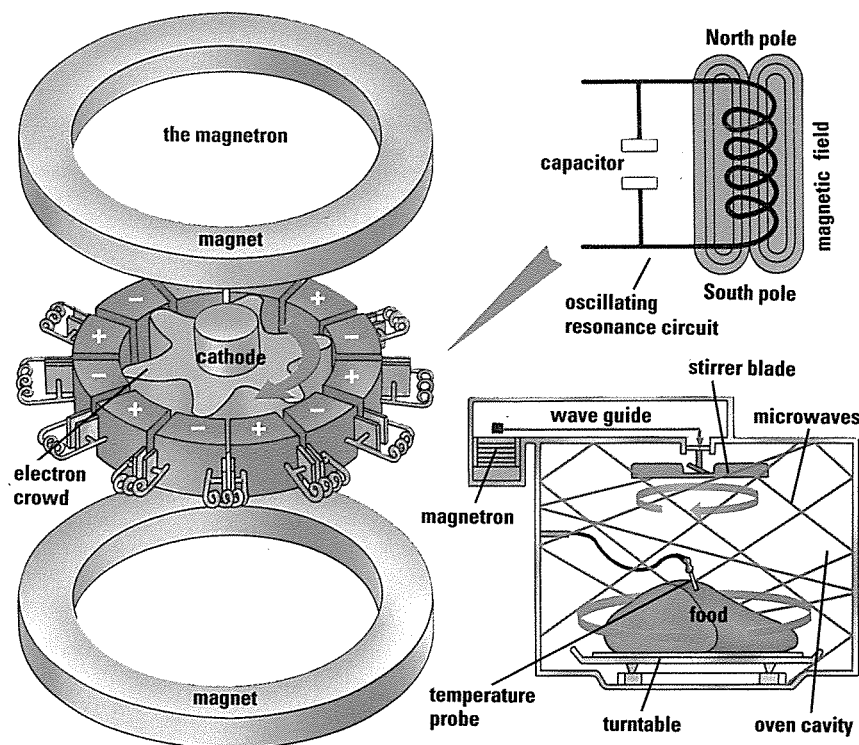
Paul Raymonde

NCAR/Science Photo Library

small as an aeroplane. Microwaves have a shorter wavelength and hence a greater ability to resolve detail.

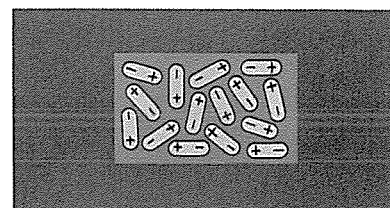
Storm warning

Microwave beams from an airliner's weather radar allow a pilot to see many kilometres ahead to spot storms. Microwaves pass straight through clear air and ice crystals. But water droplets, or hail with a film of rain water, partly reflect the radar beam, creating echoes that show up on a radar screen. These echoes are processed by computer and colour-coded so that areas of heavy rain appear red, while those of lighter rain

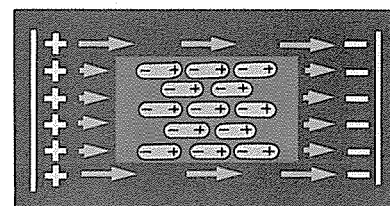


At the core of a microwave cooker is a magnetron. Inside, a heated cathode, within a magnetic field, emits electrons that crowd and spin outwards. In passing the tips of the resonance circuits the electrons cause rapid positive and negative field reversals that in turn produce microwaves.

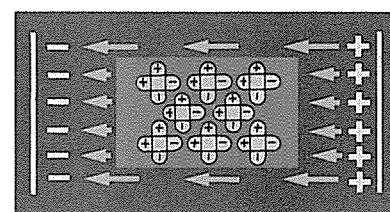
Water molecules have two magnetic poles (one positive and one negative). These molecules are randomly arranged in food (A) until aligned by applying an electrostatic field – microwaves (B). Alternating the field rapidly 'flips' the molecules (C) causing frictional heating that cooks the food.



A

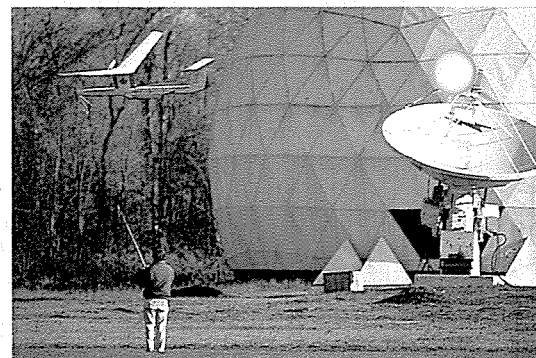


B



C

MICROWAVE PLANE



This is the world's first pilotless, microwave-powered aircraft. An operational prototype being developed from the test model, in Canada, at a cost of some £15 million, will have a fuselage 24 metres long and a wingspan of 36.5 metres. Powered by about 12 transmitters onboard and controlled from Earth, the craft will fly at twice the height of most conventional aircraft.

The microwave craft will be less expensive to operate – at around £125,000 per year – than the largest telecommunications satellite. It will also be more powerful than any satellite and capable of uninterrupted and easily controlled flight – allowing it to be brought back to Earth for data collection and repairs.

Kitted out with a transmitter the craft could serve an area 600 km in diameter. Alternatively the craft could be ideally suited to help study pollution. It could, for example, measure levels of sulphur dioxide and nitrogen oxide in the atmosphere from an altitude of 120 metres.

Daudier/Jerrican



ing it to 250°C for three minutes to kill all harmful bacteria, before sealing it in bacteria-free packages. This would increase the shelf life of some foods to years rather than days.

Destroying tumours

One very important development in the application of microwaves is in the field of medicine. It has been discovered that cancerous tumours are killed by heating them to 109°C. Some success has been achieved with microwave treatment of patients

Experimental treatment of tumours using microwaves relies on the fact that cancerous cells are more easily destroyed by heat than normal tissue.

whose cancerous cells are on or close to the surface of the skin.

Efforts are continuing to find how to heat tumours consistently and to accurately measure the temperature of tumours being treated. Work is also being carried out to reduce side effects that include burns and blistering.

Mark Franklin

Peter Menze/Science Photo Library

Q THUNDERSTORMS

Q ELECTRORECEPTORS

Q BRAINWAVES

LIVING VOLTS

Lightning strikes the ground some 6,000 times a minute – often with devastating results. In the USA alone, lightning kills over 100 people a year.

FROM MIGHTY BOLTS OF lightning to tiny currents in the human brain, electricity takes many forms in the natural world. Some animals can even detect the weak electrical waves given off by other creatures nearby.

The most awesome displays of natural electricity occur during thunderstorms. At any moment, between 1,500 and 2,000 thunderstorms are taking place around the world.

A thunderstorm starts to brew

Tony Stone Photo Library, London



Scientists are sceptical about the existence of ball lightning, but there are many eye-witness accounts. Glowing spheres up to a metre across have been seen inside closed rooms and even aircraft, as well as in the open air.

when a mass of cold air moves on top of a body of hot, humid air. Violent up and down draughts tear at the water droplets, ice crystals, and hailstones inside the developing storm-cloud, causing static electricity to build up.

● Giant battery

Smaller particles, carrying a positive charge, rise to the top of the cloud. At the same time, larger, negatively-charged drops and hailstones gather at the cloud's base. This separation of charge effectively turns the cloud into a giant battery capable of generating a sudden, enormous spark. Underneath the cloud, a positive charge is induced at ground level. A cloud-to-

Bead lightning above Los Alamos, New Mexico, USA. Sometimes the main lightning flash breaks up into luminous sections, or 'beads', as it fades.



ground lightning flash begins with an invisible discharge, called a leader, that branches downward. This carries a negative charge towards the Earth's surface and creates a trail of ionized air (ions are atoms that have been charged by stripping their electrons).

● Discharges

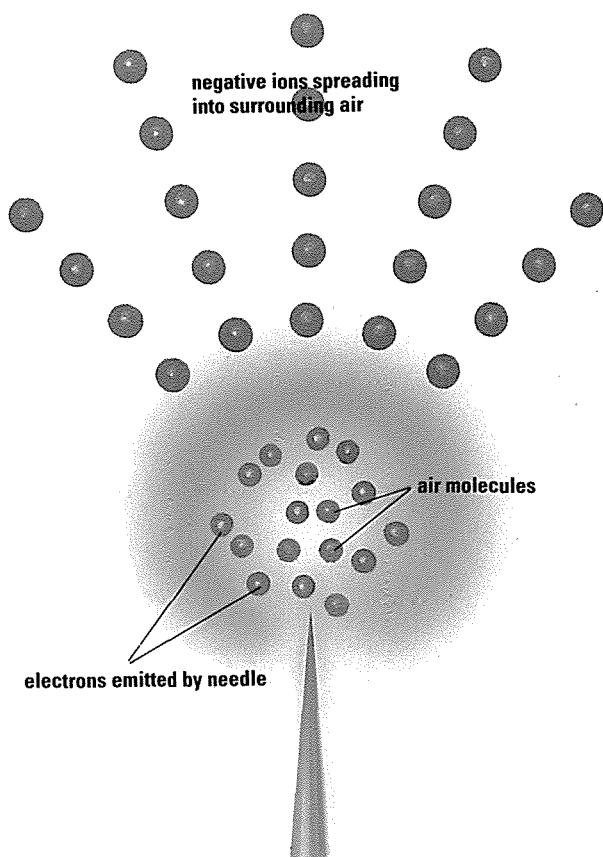
As a branch of the leader comes to within roughly 100 metres of the ground, the negative charge in the air attracts the positive charge near the ground. Discharges then form at the ground and travel upwards until they meet the leader. When contact is made, the first bright return stroke occurs. This is the start of the lightning strike. The return stroke, with a peak current of between 10,000 and 40,000 amps, races back up the trail of ionized air into the cloud.

● The leader

After a pause of a few tens of micro-seconds, another leader comes down, triggering a second return stroke. Most lightning flashes consist of three or four leaders and return strokes, though as many as 40 have been observed. The bright flash we see comes from the upward moving return strokes.

Sometimes a leader travels only part of the way down an existing ionized channel, then forges a different

How an Air Ionizer Works



Ions are tiny electrically charged particles in the air; negative ions are air molecules that have acquired an extra electron. When the level of negative ions in air indoors and in cities is increased, people become less tense and more alert. Negative air ions can be created in an air ionizer by sending high voltage electrical charges through one or more needles. High velocity electrons are emitted by the electric field at the tip of the needle.



Andy Best/Met Office

One flash of cloud-to-ground lightning strikes at one two-thousandth the speed of light with a power of up to 200,000 amps. This tree in Utah, USA, was struck by such a force.

ELECTRIC EELS



Hans Reinhard/Bruce Coleman Ltd

The electric eel of South America is one of the few creatures in the world that can kill its prey by electrocution. Measuring up to 2.5 metres in length and 22 kg in weight, the electric eel has three pairs of electric organs on each side of its body. These living batteries can produce either a continuous, low-voltage discharge to help sense the surroundings or a sudden shock, strong enough to stun a man. At full strength, the eel can generate 650 volts, usually in three to five bursts lasting about two thousandths of a second.

path to the ground. In such cases, forked lightning is seen. On other occasions, discharges take place between neighbouring clouds without reaching the surface at all. This gives rise to sheet lightning.

Because lightning usually seeks out the highest object, tall or isolated trees and exposed hill tops are especially dangerous places to be in a thunderstorm. Metal structures are also a hazard.

Blue sparks

In 1955, at the racecourse in Ascot, southern England, lightning ripped along metal railings in a series of blue sparks that jolted nearby spectators over a metre into the air. Two people were killed and 47 were injured.

Metal jewellery, such as a medalion, has been known to draw lightning. Even making a phone call during a thunderstorm has its risks. In 1988, a woman in Sheffield, England, was burned on her ear and thigh when lightning struck the telephone wires and passed through her body.

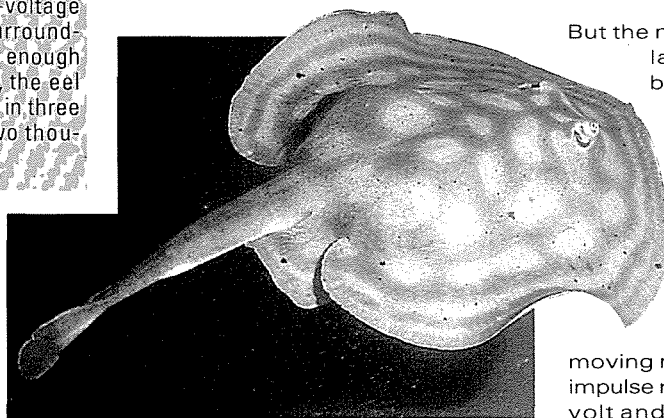
Ball lightning

A single flash can carry over 10,000 amps at 30,000°C – more than enough to reduce human flesh and bone to ashes. Whether or not a lightning strike is deadly, depends on the path it takes through the body to the ground. About three-quarters of those

who are struck suffer only burns. However, if most of the current passes through a major organ, such as the brain or heart, it can kill.

Less common and more mysterious than ordinary lightning is ball lightning. This occurs during thunderstorms, though it has been seen in fair weather too. A typical 'ball' measures some 25 cm across and glows a pale

Testing for deafness. A device called the Nicolet Pathfinder measures tiny changes in the brain's electrical activity caused by sounds sent through the baby's headphones. The changes are recorded by an EEG. By comparing the output (seen on screen) with 'normal' results, hearing problems can be identified.



But the mechanism by which such a large amount of energy can be contained in such a compact form for so long is not well understood.

Natural electricity on a much smaller scale is vital to the functioning of our bodies. Electrical signals travelling along nerve cells to and from the brain allow us to sense our surroundings and to respond by moving muscles. An individual nerve impulse registers less than a tenth of a volt and travels at a speed of up to

Alexander Tsiras/Science Photo Library

An electric ray stuns the fish on which it preys with a powerful electric current produced by organs in the head and back. This can measure up to 220 volts.

The platypus, found only in eastern Australia and Tasmania, locates its prey by detecting the weak electric fields radiated by other animals with its leathery, sensitive, duck-like bill.



red or orange colour. It may have a halo around it or give off sparks. Ball lightning can last for a minute, or even longer, before either exploding violently or simply fading away.

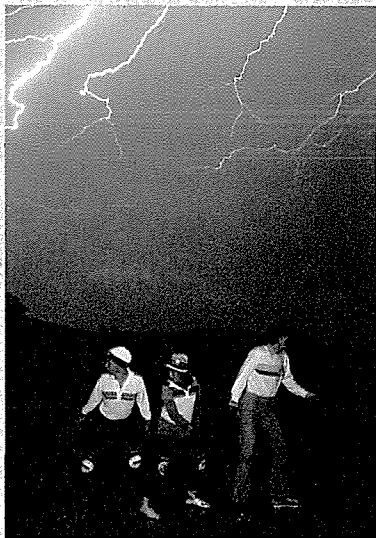
Strangest of all, ball lightning has a

100 metres per second. This means that the longest delay for an impulse making a round trip between the brain and any part of the body is less than 0.04 of a second.

Each nerve cell, called a *neuron*, is

Roy Manstan/Planet Earth Pictures ANT/NHPA

SAFETY TIPS IN THUNDERSTORMS



Gamma/Frank Spooner Pictures

If you are outside:

- Run for shelter (a building or car) but avoid small sheds or tents in open areas
- Stay clear of tall objects such as trees, telephone poles and boat masts
- Get out of and away from water
- Avoid metal objects, such as traffic signs, posts and fences
- If you are with a group of people, make sure you are at least 10 metres away from each other
- Squat with your knees tucked together. Do not lie on the ground!

If you are inside:

- Do not stand or sit near doors or windows
- Turn off TVs, stereos, computers and radios and do not use the telephone
- Do not take a bath or shower, or wash anything in the sink.

water, for instance. Some animals, such as the duck-billed platypus, are equipped to sense these fields, which help them to navigate and find food. The side of its bill is lined with a number of electroreceptors that react to impulses as low as 20 millivolts (thousandths of a volt) occurring at a rate of up to 600 per second.

Electrical signals

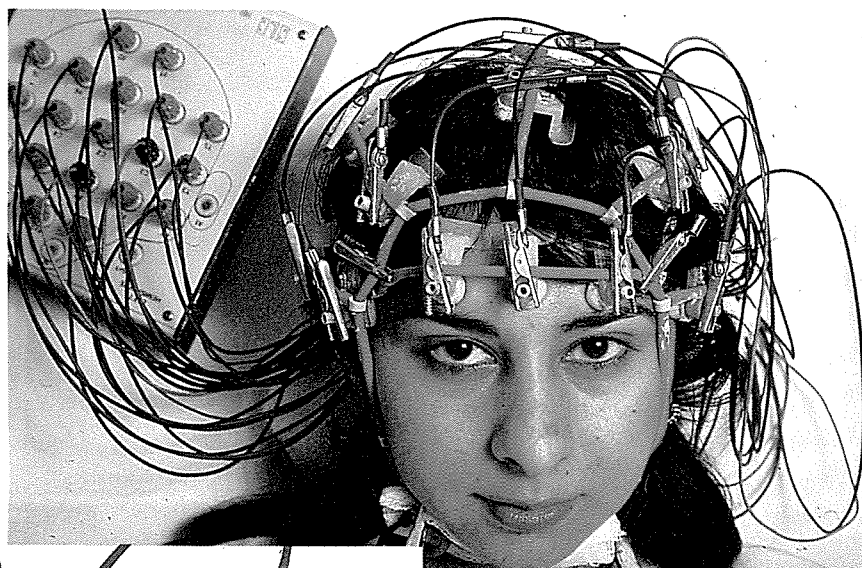
This means that the platypus can sense, for example, the tiny electrical signals passing between nerves and muscles in the tail of a shrimp – a favourite prey. The snout of the spiny anteater, another Australian mammal, can also detect electrical waves.

Sharks, and certain other fishes as well, have electroreceptors in their bodies. The shark's face is pitted with hundreds of minute holes, called the ampullae of Lorenzini, which can pick up the electrical waves radiated by fish swimming nearby.

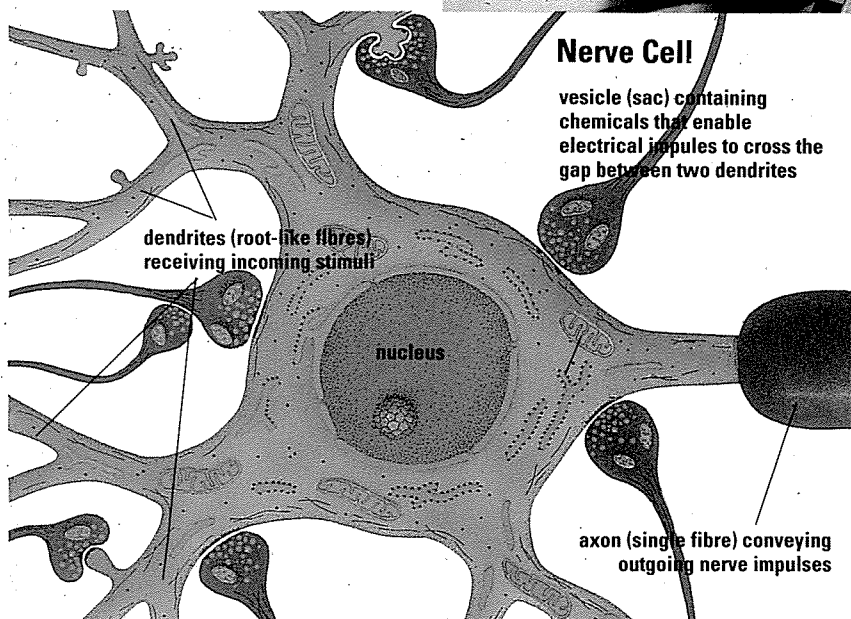
like a tiny, insulated wire. The nerve impulse moves along the narrow conducting fibre in the centre. A surrounding sheath made of the protein myelin acts in the same way as plastic insulation around an ordinary electric wire.

The end of each neuron branches out into many tiny pathways, known as *dendrites*. These are separated from the dendrites of neighbouring neurons by narrow gaps called *synapses*. For the short hop across a synapse, signals are transferred chemically rather than electrically.

The greatest concentration of neurons – about 10 billion of them – is in the brain itself. Millions of electrical impulses criss-cross the brain each second, even while we are asleep.



Jerry Mason/Science Photo Library



Nerve Cell

vesicle (sac) containing chemicals that enable electrical impulses to cross the gap between two dendrites

dendrites (root-like fibres) receiving incoming stimuli

nucleus

axon (single fibre) conveying outgoing nerve impulses

Electric currents that pass through the brain can be recorded by an EEG, properly called an electroencephalograph.

Collectively, these impulses are responsible for all our thoughts, memories and sensations.

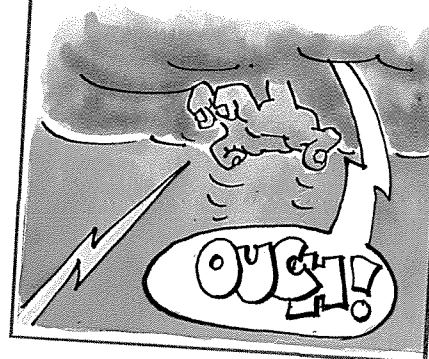
Weak electric fields are produced by all living creatures as well as by many non-living objects – streams of

Electric impulses, sent from one nerve cell to the next, travel to the brain with information about the body's surroundings, then out again with instructions on how the body should react.

Just amazing!

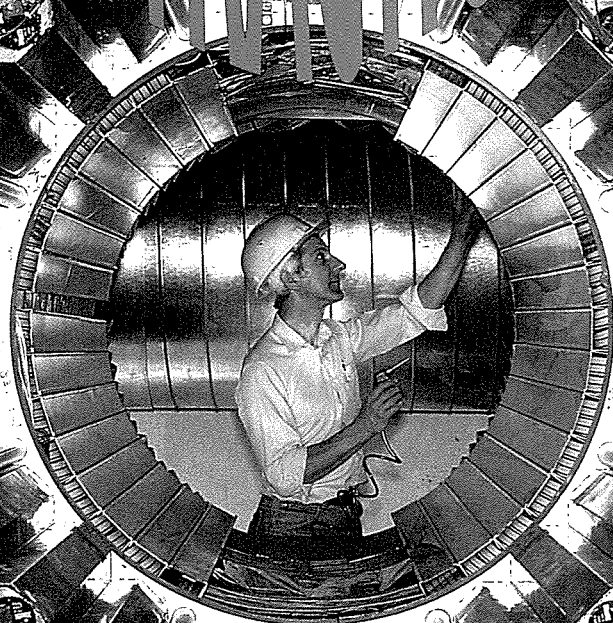
THE BIG HEAT

A FLASH OF LIGHTNING CAN REACH TEMPERATURES AS HIGH AS 30,000°C – MORE THAN FIVE TIMES THE HEAT OF THE SURFACE OF THE SUN.



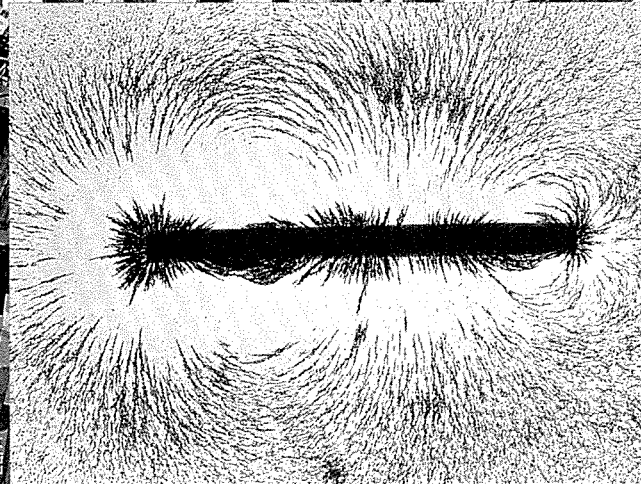
Paul Raymond

NATURAL ATTRACTION



AT THE HEART OF MODERN technology such as motors, videotape recorders and atom smashers lies one of the fundamental natural forces: magnetism.

In ancient times it was known that a type of iron ore called magnetite attracted certain metals, such as iron, nickel and cobalt. Magnetite was once commonly called lodestone, which means 'guiding stone', because it was discovered - originally by the Chinese - that if a light, thin 'needle' of magnetite was pivoted, it would always swing so that it pointed roughly in a north-south direction. The end that is attracted to the north is called the magnet's north pole; the end that



A particle detector at the European Centre for Particle Physics near Geneva. Subatomic particles are bent into a curved path by the magnetic field and are then smashed together.

The magnetic field of a bar magnet is shown by iron filings that group along the lines of force, forming closed loops around the poles.

is attracted to the south is called the magnet's south pole. Every magnet has two such poles. The magnetic attraction seems to be centred in them. If a bar-shaped magnet is dipped into iron filings, they will cluster around its poles – few will cling to the central part of the magnet.

Magnetic attraction

If a magnet is cut in half, new poles will appear, so that each of the pieces has both a north and a south pole. If the two pieces are put together, pole to pole, the opposite poles will cancel each other out. The two combined will be just the same as the single original magnet.

A magnetized piece of iron is divided into millions of regions called 'domains', typically from 1/100 to 1/10 cm across, and visible under the microscope. If these tiny 'magnets' point the same way, their magnetism will combine, making the whole piece of iron into a magnet. If they become

disordered, pointed in all directions, they will cancel each other out. Though each domain continues to be a small magnet, the iron as a whole loses its magnetism.

If you place two magnets close to each other, you will soon find that their north poles repel each other (push each other away), while the

north pole of one attracts the south pole of the other – 'like poles repel, unlike poles attract'.

Wandering poles

We know that the Earth behaves like a magnet from using a compass, therefore the Earth also has north and south magnetic poles.

These 'geomagnetic' poles lie 1,400–2750 km from the geographical poles at present, but they wander erratically around over the course of centuries. (Since the north magnetic pole attracts the north-seeking end of a compass needle, and since unlike poles attract, it is itself a south-seeking pole!)

A magnetic compass is useless anywhere near the geomagnetic poles. Even

A mariner's compass showing a 360° conical card that rests on a jewelled bearing in a bowl filled with liquids. The pointer, at approximately 330°, shows the sailor his compass bearing.

A levitating magnet above a superconductor. The powerful magnetic fields created by superconductors can be used as the basis for magnetic levitation – MAGLEV – trains.



The Earth's magnetic field – the magnetosphere – is distorted by the solar wind. Charged particles from the Sun are trapped in spiral paths in radiation belts known as Van Allen belts.

The Earth's Magnetic Neighbourhood

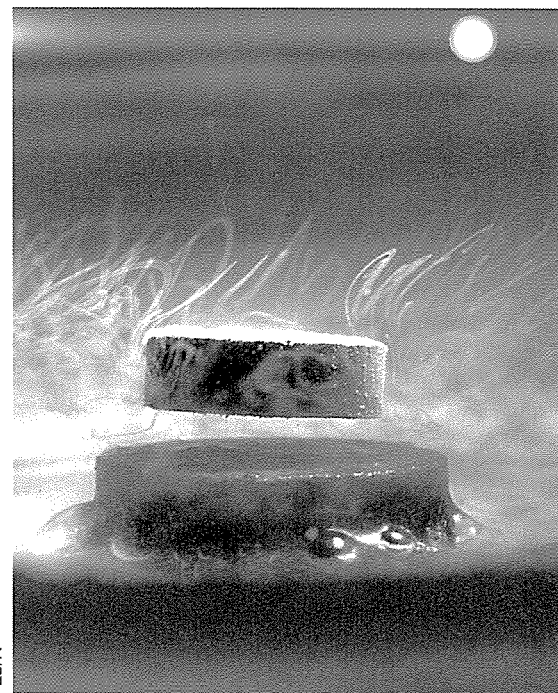
trapped solar particles

Van Allen belts

magnetic field direction

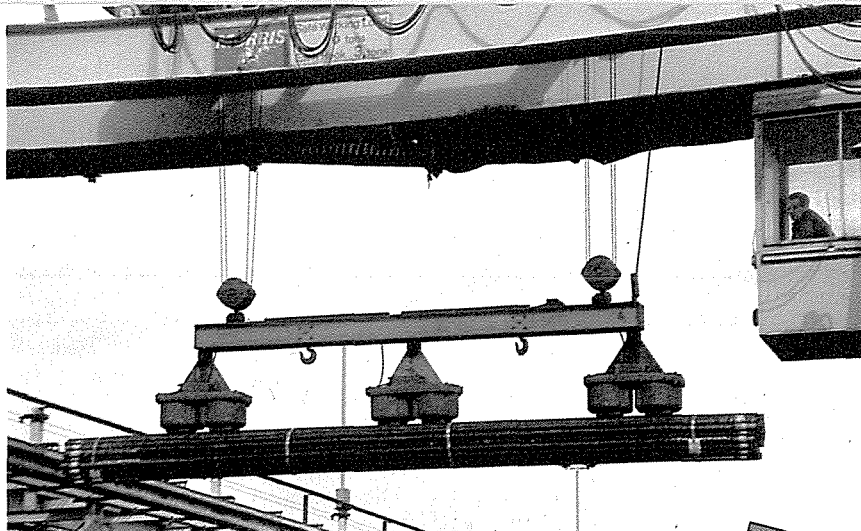
solar particles

solar wind



elsewhere, it is necessary to know the magnetic 'declination' – the angle between true north and the direction shown by a compass. This information is recorded in tables or on maps, that have to be updated every year.

The influence of a magnet may be pictured by means of 'lines of force'. At every point around the magnet the direction of the line of force through it shows the direction of the magnetic force – as shown, for example, by the



direction in which a small magnetic compass placed at that point would lie. The direction of the line is defined as being from the magnet's north pole toward its south pole.

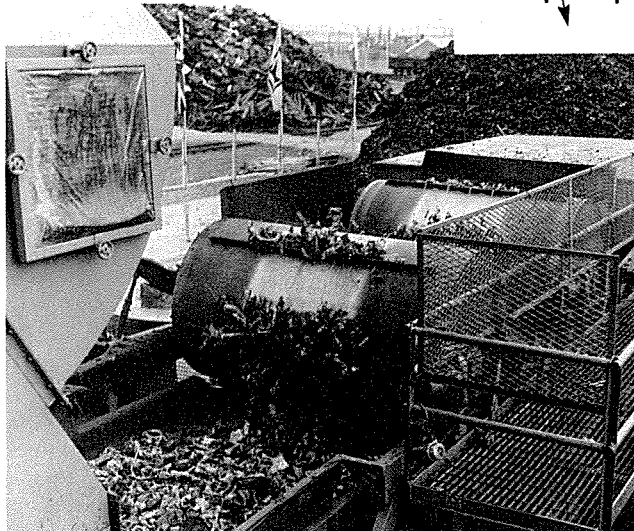
Lines of force spread out from a magnet's north pole, loop around it, then vanish into its south pole. They are crowded together where the

Industrial magnets use a powerful electromagnet to lift bundles of bars. The electric current is switched off to release the load once it is in position.

Recycling metal, from shredded waste, is easily achieved by magnetic drum separators. The metal is then added to new iron or steel ingots in a furnace.

A Kirlian photograph of an electric discharge. This 'artificial lightning' has been created by dropping a small steel ball into a high-energy electrical field.

Eriez Magnetics UK Ltd



NATURAL ATTRACTION

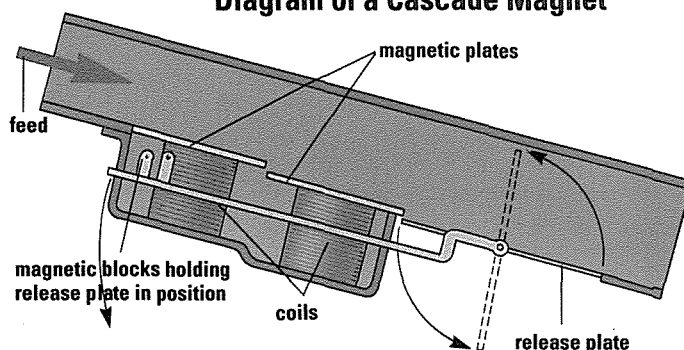
produce a field like that of a bar magnet. Such an electromagnet is convenient, since it can be turned on and off. And the more turns of wire it has, and the larger the current through the wire, the more powerful the electromagnet. It can be made more powerful yet by winding the coil round a piece of iron.

Atom smashers

Electromagnets are used for handling iron, steel and other magnetic metals. In scrapyards, for example, cranes

Mark Franklin

Diagram of a Cascade Magnet



A Cascade Magnet is used to remove metal contamination from dry, free-flowing materials. Its soft iron core is magnetised when electric current is passed through the wire coiled around it. Unlike permanent magnets, the electromagnet loses its magnetic properties when the surrounding current is stopped.

GAMMA RAYS

The first blow in a nuclear attack could consist of a wave of gamma rays – a type of electromagnetic radiation. If a one-megaton hydrogen bomb (an average-sized nuclear weapon) were exploded in space, about 400 km high, a pulse of gamma rays would flood the Earth below. These would not threaten life directly, but would knock out electrical equipment.

If the bomb were exploded above the central United States, unprotected electrical and electronic equipment from the East coast to the West Coast would be affected. Military equipment can be specially protected against this EMP (electromagnetic pulse), but civilian equipment, especially radios, televisions and computers, would be heavily damaged at a single stroke – and before the first bomb had gone off at low altitudes.

equipped with electromagnets instead of hooks are used to pick up cars. Electromagnets are also used in giant metal shredders to separate scrap made of magnetic metal from other sorts of scrap.

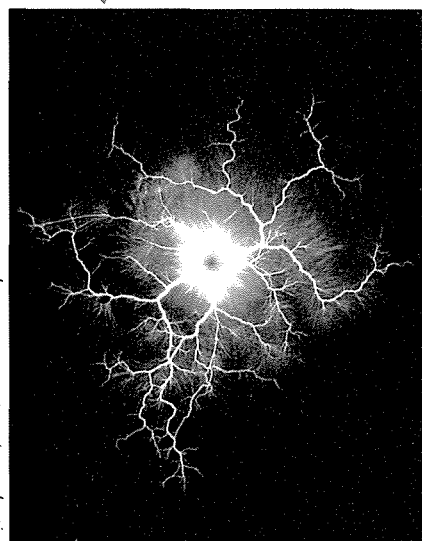
Powerful electromagnets guide subatomic particles in accelerators ('atom-smashing' machines) used in nuclear research to investigate the

fields. Imagine a wire stretching vertically up out of this page. Imagine further that the Earth's magnetic field is shut out by enclosing the experiment in a metal cage. Now an electric current is switched on in the wire. The current consists of a stream of tiny particles called electrons, moving upwards along the wire.

Circular field

A small compass placed close to the wire will turn until it is pointing along the circumference of a circle centred on the wire. When the field lines are mapped with the aid of the compass, or with iron filings scattered on the page, they are found to be circles centred on the wire. Since they do not come together or spread out, this magnetic field has no poles. However, the field grows weaker farther away from the wire.

The wire can be made into an electromagnet that mimics a bar magnet. It is looped many times into a cylindrical coil and the magnetic fields of all the turns of wire add together to



Henry Dakin/Science Photo Library

magnetism is strongest. The pattern formed by these lines of force is known as the 'field' of the magnet.

One of the most momentous discoveries in the history of science was that electric currents create magnetic

MAGNETIC STORMS

Magnetic compasses occasionally go awry, swinging back and forth, away from the true direction of magnetic north. At the same time radio transmissions may be disturbed, and power supplies may be disrupted. The cause lies 150 million kilometres away, in the Sun. Such a 'magnetic storm' is triggered some hours after a burst of high-energy particles has been fired into Space by a solar flare, a huge explosion on the Sun. The particles arrive at the Earth and are caught in the two Van Allen radiation belts – stores of trapped particles 10,200 km and 23,600 km high. This sudden flood of particles causes some of the contents of the belts to spill over and spiral down towards the magnetic poles along magnetic lines of force. As they do so they create wildly fluctuating fields that disturb compasses and generate stray voltages in electrical equipment.

many particles within the atom. The particles circulate around giant 'race-tracks', such as one near Geneva that is 27 km in circumference.

They move at close to the speed of light, being boosted electrically on every 'lap', so that they pick up more and more energy. Finally they smash into a target, such as a block of metal, or are 'collided' with another beam of particles. The particles are forced to

Earth, this results in a steady but complicated flow of fluid iron. This causes electric currents to flow in the core and create a magnetic field.

The Earth's field is very poorly understood. In particular, it is not known why it should fade away and then reappear, pointing the opposite way roughly every half-million years.

Sound and pictures

Magnetism is an important means of recording sound, video pictures and computer data. An audio tape consists of a thin film of polyester coated with a binder through which are dispersed needle-shaped particles of

Auroras occur mostly over polar latitudes and are caused by the collision of air molecules in the upper atmosphere with electrically charged particles from the Sun.

Magnetic tape is used for sound recording. The tape consists of a layer of powdered magnetic material, which registers the signals to be reproduced later as sound.



National Centre for Atmospheric Research

struck the recording microphones.

Recording a videotape works in much the same way, except that in addition to a track for the sound channel, the picture signal is laid down in a series of thin diagonal stripes, in order to pack in the vast amount of information that is needed to represent a television picture. A television picture represents an image as lines of dots. The pattern of magnetization on the videotape corresponds to those dots.

follow their curved paths by magnetic fields up to 20,000 times as strong as the Earth's. The electromagnets producing the field have to be positioned to within a fraction of a millimetre.

Electric currents

The Earth is not just a magnet but an electromagnet. Geomagnetism is caused by electric currents flowing in its iron core. The central core is crushed by huge pressure into a solid form, but the outer core is liquid iron. Hot fluid iron rises from deep in the outer core, cools and sinks again.

Combined with the rotation of the

iron oxide or chromium dioxide.

When a sound recording is made, the tape passes close to a recording head, which contains an electromagnet. The strength of the current through the recording head, and hence the strength of its magnetic field, varies according to the strength of the sound that is being recorded.

Four track recording

The field from the recording head magnetizes a small section of the magnetic oxide coating. Where the field is strong the particles of the coating become strongly magnetized. As

Just amazing!

HUMAN MAGNETS

IN 1920 INMATES OF A PRISON IN NEW YORK, USA, WHILE SUFFERING FROM FOOD POISONING, WERE REPORTED TO BE ABLE TO DEFLECT COMPASS NEEDLES AND ATTRACT METAL.



Paul Raymond

ROCK WATON

Patrick Baker/Bruce Coleman Ltd

THE SHALLOW BEDS OF seas around the world are rich in a variety of useful minerals, animals and plants. But harvesting these resources can present a challenge to both men and machines.

Seabeds are the source of much of the sand and gravel needed for the building industry. Britain alone uses about 100 million tonnes annually, of which 10 per cent is pumped from the shallow waters of the continental shelf by dredgers and dumped into waiting barges. Major deposits of shells, such as those off the Bahamas, are also mined extensively as a source of lime for agriculture or for use in making cement.

Metal deposits

Being heavier than other rock fragments, metals tend to concentrate on the seabed. Rain and wind erode metal ores on land, and rivers then carry the particles of ore into the sea. The heavy specks of metal settle out of the water first, forming metal-rich sands called placer deposits. These usually start off as beach deposits, but as the sea-level changes and shorelines move with time, many placer deposits are now found

situated on the continental shelves.

Like sand and gravel, they can be mined by dredging. Gold has been obtained from placer deposits in Alaska, diamonds off the coast of Africa and ores of the metals titanium and zirconium in Australian waters.

Giant kelp

As knowledge of the structure and composition of the Earth's crust increases, geologists can predict the location of new sources of these and other minerals.

Ice-cream, toothpaste, plastics,

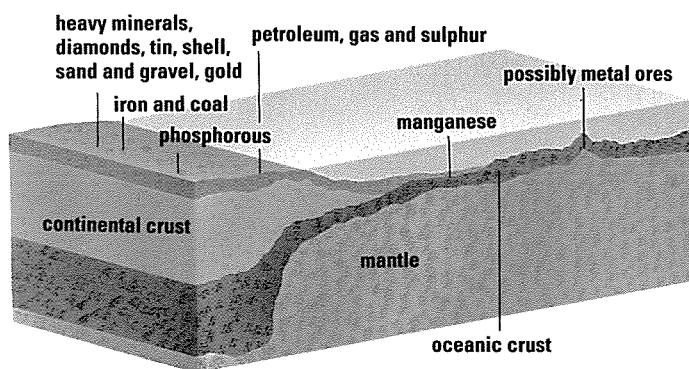
Shallow water dredges are dragged across the seabed by dredgers to recover minerals. Posidonia Australis (top), one of the few marine flowering plants, is used to make sackings.

paint, make-up and medicines are among the many products made using seaweed. An enormous type of seaweed called Pacific giant kelp is found off the west coast of America. Measuring up to 60 m in length, it can grow 45 cm in a day.

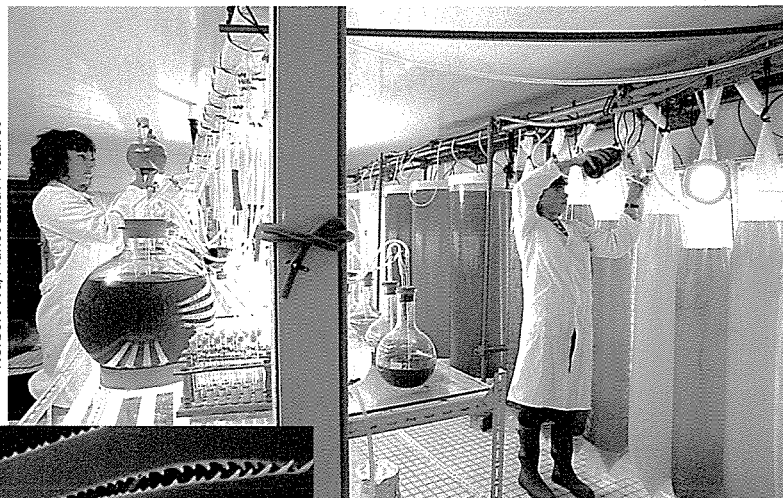
The kelp is harvested by back-



Nicholas Penn/Planet Earth Pictures



Norbert Wu/Planet Earth Pictures

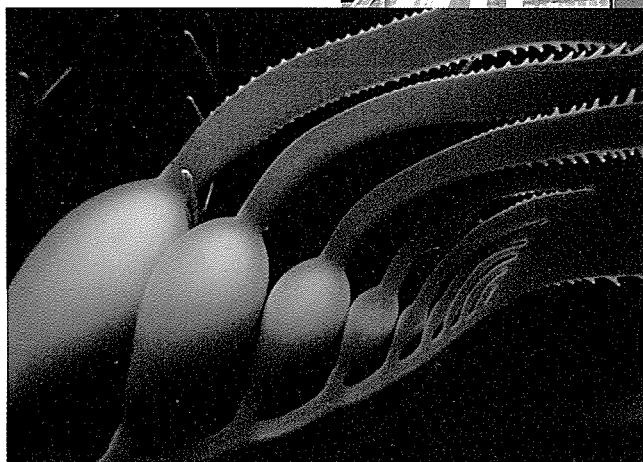


Mark Franklin

Valuable mineral resources on the seabed can be surveyed in shallow continental shelf waters by divers while at deeper levels, drilling and other techniques are used to locate the deposits.

ward-moving boats that slice the tops off the plants with sharp, revolving blades and then drag them aboard. Later, the kelp is boiled in large vats and the jelly-like extract from it is used in manufacturing. Whole plants can be turned directly into animal feed and fertilizer.

The Japanese consume great quantities of seaweed, much of which is cultivated on special nets in Japan's shallow Inland Sea. Another edible seaweed, a delicate, red variety, grows naturally around Japan's shores and is collected from small boats using long, hooked poles.



Seaweed is now being used for a variety of high quality products such as a range of cosmetics, a type of dietary bread and a drink in which the plant is combined with sea water.

Ivaldi/Jerrican

Kelp bulbs are not damaged by harvesting since the plant's long streamers are cut to just under a metre beneath the water. Cutting can even contribute to growth by allowing greater amounts of sunlight to reach the plants.

Gamma/Frank Spooner Pictures

Oysters

Oysters, clams, and shrimp are among the animals farmed in the sea. One oyster produces millions of eggs, which soon hatch into free-swimming larvae. The larvae attach themselves to any hard surface, normally a rock, and then develop into small oysters known as spat.

Oyster farmers distribute old oyster shells or even roofing tiles around the spawning grounds. They then collect these when coated with spat and transfer them to the shallow waters of a bay or estuary that has been cleared of starfish and other animals that eat oysters. Supported on wooden racks or suspended from wires, the oysters grow until they are ready to be harvested.

Pearls

A certain type of oyster, not the edible kind, produces pearls. This happens when a speck of grit gets inside the oyster's shell and acts as an irritant. The oyster builds up layers of a hard, lustrous chemical around the grit to protect itself.

In certain parts of Asia, skilled divers can stay underwater for several minutes while they search for natural pearl oysters on the seabed. But many pearls now come from farms in which tiny pieces of shell are placed inside the oysters. After three years, the oysters are opened and the so-called 'cultured' pearls removed.

Bathroom sponges

Most bathroom sponges today are man-made. However, the expensive, oddly-shaped, yellow sponges that you occasionally see on sale are the

soft skeletons of primitive animals that live on the seabed.

Sponges have been found at all depths, from the shallows of inland seas to the ocean floor 6,000 metres down. They obtain oxygen and food by circulating seawater through the numerous channels in their bodies.

Only a few varieties can be used as bathroom sponges. These are collected by divers working as deep as 30 metres without any special equipment. At first, the living sponges are greyish and slimy. To clean them, they are washed, stamped on, or beaten. Then the skeleton is trimmed with a knife ready to be sold.

Just amazing!

PEARLY KING

THE LARGEST PEARL EVERY FOUND, THE PEARL OF ALLAH, CAME FROM A GIANT CLAM IN THE PHILIPPINES. IT WEIGHED 6.4 KG AND MEASURED 24 CM LONG BY 14 CM ACROSS.



Paul Raymond

GENERATORS

ELECTRONS

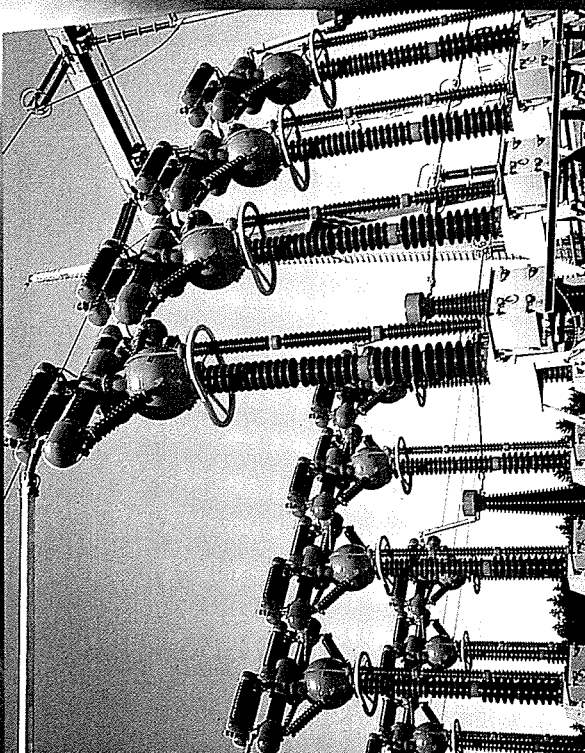
POWER STATIONS

ELECTRICITY

A discharge of electricity flashes from one metal object to another. Metal has the kind of molecular structure that makes it an ideal conductor, so that it naturally attracts any unchannelled electricity.

WITH THE FLICK OF A SWITCH, a light, a stereo, a microwave oven or a computer comes instantly to life. These devices, and thousands of others that we take for granted in the modern world, work off electricity. But what is electricity and where does it come from?

An electrical current is a flow of tiny particles called electrons. Electrons are one of the basic building blocks of atoms, and are negatively charged; this means that they repel each other. Normally, the electrons swarm in clouds around the atom's nucleus, or centre, made up of a cluster of positively charged protons and neutrons. In some atoms, however,

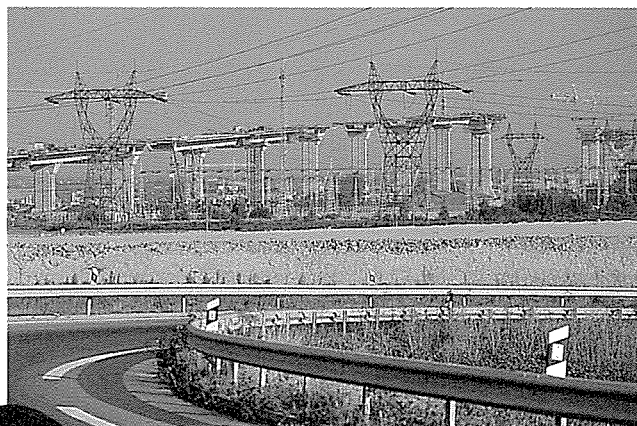


Circuit breakers, like these ones at an electricity substation at Oregon City, USA, are a safety device. If lightning strikes an overhead cable, the circuit breakers switch off power to the rest of the cable to protect it.

some of the electrons are 'free' and orbit outside the atom. These free-electrons can travel in streams from one place to another, creating a current of electricity.

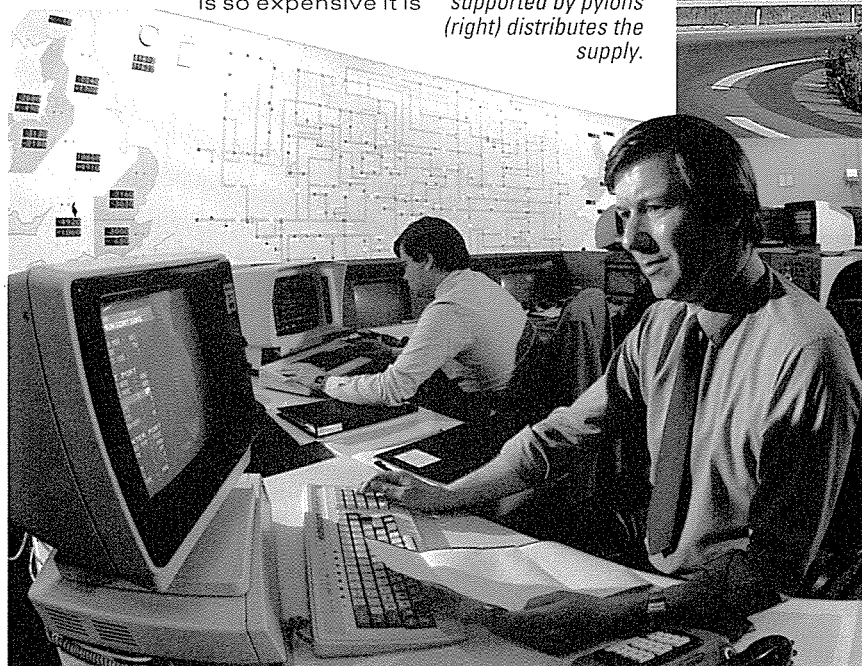
Substances such as metals, which contain many free or loosely held electrons, are known as conductors, since they allow electricity to pass through them very easily. Silver is one of the best conductors, but because it is so expensive it is

The control room of a national grid system is the nerve centre of a country's electricity supply. Here, supply can be monitored, and then redirected to where it is most needed. A network of cables supported by pylons (right) distributes the supply.



Berenguer/Jerrican

National Grid Co



sible circuits – a battery provides a supply of electrons, which flow through a wire to a bulb and then back again to the battery. Although the wire is a good conductor, some electrons do collide with the atoms in the wire, which slows them down. This slowing down effect is known as resistance.

Glowing filament

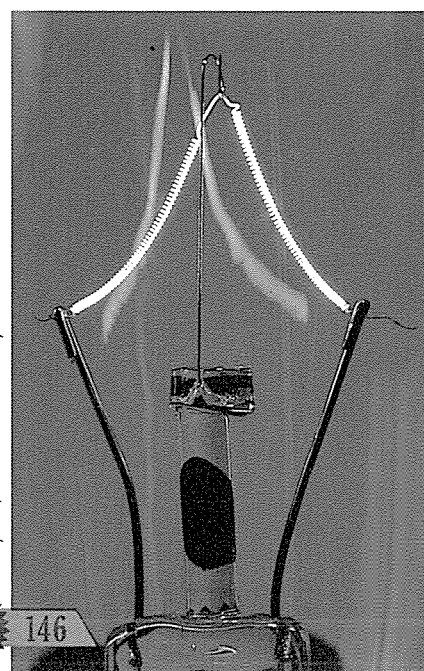
Inside the light bulb, a very thin wire or filament offers much more resistance to the electrons as they squeeze through it. But so many collisions occur in the filament that it quickly becomes hot and begins to glow.

A battery supplies one-way, or direct current (DC). But mains electricity is constantly changing direction and is

used only for the most crucial connections in devices such as computers. The best low-cost conductor, used for virtually all wiring, is copper.

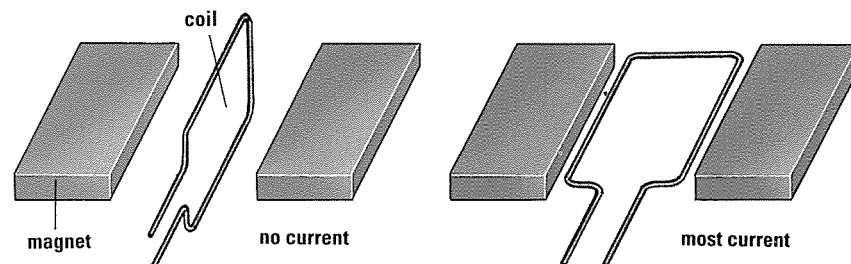
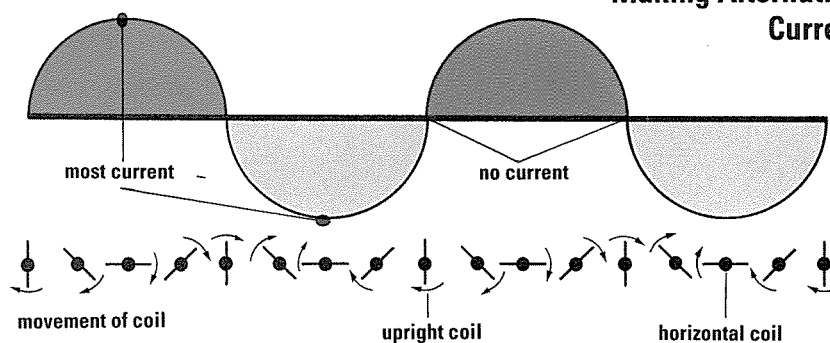
Most other materials, including plastics, ceramics, rubber, wood and paper, have very few free electrons and so prevent electricity from flowing through them. They are called insulators. Household wiring, for

The filament in a light bulb is made of very fine wire. Electrons keep bumping into the atoms in the wire, making them vibrate and glow white with heat.



Ray Ellis/Science Photo Library

Making Alternating Current



Mark Franklin

instance, consists of a bundle of current-carrying copper wire, surrounded by an insulating layer of plastic to prevent the current from escaping. Devices that produce high temperatures, such as electric oven rings and car engines, need better insulation, so ceramic insulators are used instead of plastics.

The path an electric current takes as it flows is called a circuit. In a torch, for example – one of the simplest pos-

Electricity can be generated by rotating a coil in a magnetic field. This produces a current that varies (top) according to the position of the coil.

known as alternating current (AC). The frequency of change varies from one country to another but is in the range 50 to 60 times per second.

Mains electricity is made in power stations. It is then sent through a

How a Turbine Generator Works

generator turned by turbine shaft
to make electricitysteam
rushes past
turbine blades
and makes
them turn

Trevor Hill

turbine shaft

turbine blades

condenser turns steam back into
water, water is fed into boiler and
turns to steam again

network of cables known as a national grid to all parts of the country.

In the power station, heat from burning coal or oil, or from a nuclear reactor, is used to convert water into steam for turning the blades of a huge turbine. A shaft from the turbine is

HIGH-SPEED POWER

The flow of electricity through a wire can be likened to the movement of water down a pipe. The rate at which water passes through the pipe depends on the pipe's width and on the difference in water pressure between the two ends of the pipe.

In the same way, the amount of current flowing through a circuit depends on the resistance of the circuit – which is measured in ohms – and the voltage – which is measured in volts. A 9-volt battery, for example, will produce six times more current through a given circuit than a 1.5-volt battery.

Current is measured in amperes, or amps. One ampere represents a flow of about 6.3 million trillion individual electrons per second.

connected to a generator in which magnets are made to spin rapidly inside a large copper coil. The rotation of the magnets produces a huge amount of current in the coil.

The force with which electrical current is driven through cables is measured in volts. The higher the voltage, the less electricity is 'lost' through

Steam forcing its way past the angled turbine blades turns the shaft. This turns an electromagnet inside a coil, which makes electricity in the same way as turning a coil in a magnetic field. The steam comes from burning coal or oil or (right) a nuclear reactor.

resistance and heating of the cable. So, before electricity leaves the power station, the voltage is stepped up from between 10,000 and 30,000 volts to between 100,000 and 400,000 volts.

This is easily done with the help of a transformer consisting of two coils of wire wrapped around opposite sides of an iron core. If the number of turns in the outgoing, or secondary, coil is greater than the number of turns in the incoming, or primary, coil then the voltage will be increased. If the situation is reversed, the voltage is similarly decreased.

Step-down

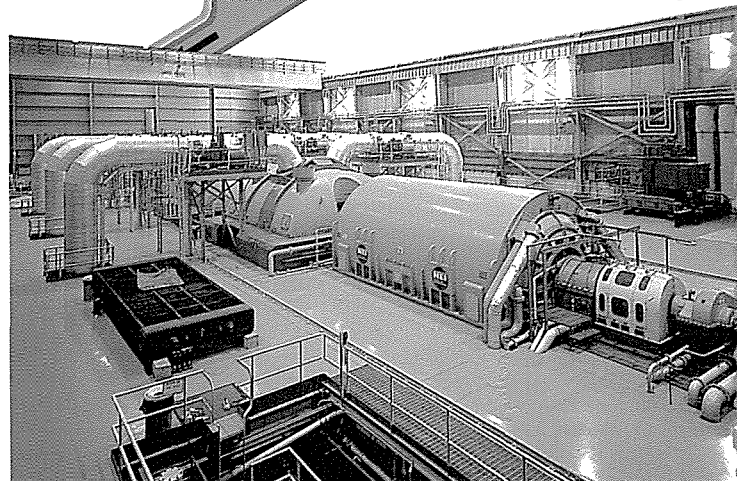
Upon reaching the outskirts of a town or city, the power lines enter a substation where the voltage is decreased by a step-down transformer until it is again between 10,000 and 30,000 volts. This reduces the danger if

power lines come down in heavily-populated areas.

Before electricity is allowed to enter people's homes, the voltage is once more reduced by a transformer in a smaller substation. The final domestic supply ranges between 110 volts in the United States to 230 volts in Britain. Large factories often have their own transformers because they need a higher voltage supply.

Switching power

By linking power stations and transmission lines together through a national grid, power can be switched from one area of a country to another as demand changes. But even this is sometimes not enough. When, in 1990, the estimated 30 million British television viewers of the England-West Germany World Cup semi-final turned on their electric kettles at half-time, the extra power drain was



Alex Bartel/SPL



so great that it affected the picture quality on many television sets!

All domestic electricity supplies are carried from the nearest substation by at least two wires, usually underground. These wires enter a fusebox where a number of fuses protect the circuits and appliances inside the house. A fuse is simply a wire that overheats and melts if too much electricity passes through it.

● 'Ring' main

Several circuits branch out from the fusebox. One type powers the ceiling and wall lights. Another is the main 'ring' circuit that runs around the house, between the walls and under the floorboards. Each circuit consists of a live wire and a neutral wire – which are both connected to the sub-

A new generation of superconducting materials were discovered in 1987. This is a computer model of the molecular structure of one of them – yttrium-barium-copper oxide.

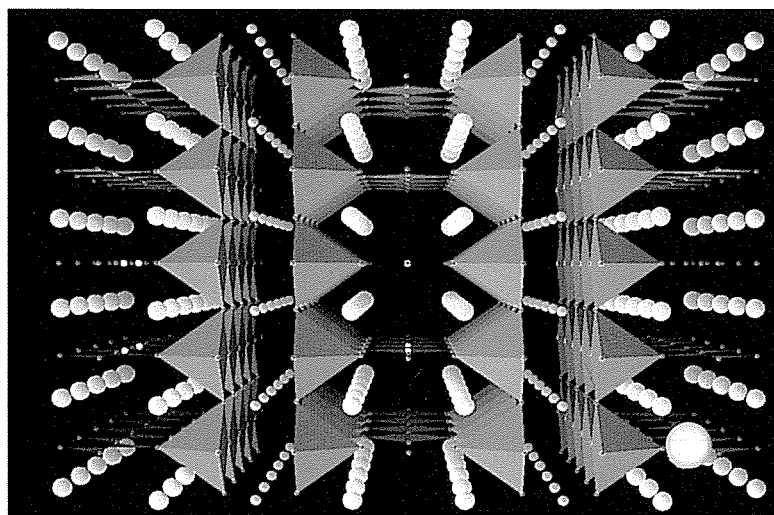
Superconductivity is the wave of the future. Conductors at temperatures nearing -273°C – absolute zero – have almost no resistance to electricity. This means that a magnet can be held suspended in a loop of super-cold wire.

wastes energy. But if a substance is cooled down to a very low temperature, it loses its electrical resistance altogether. It is then said to be 'superconducting'. With no resistance to slow it down, a current could theoretically flow around a superconducting circuit forever.

● Warm superconductors

Until recently, the highest temperature at which a substance was known to superconduct was -250°C ; the conductor was a metallic niobium-germanium alloy. But in 1986, there was a major breakthrough. Scientists discovered a number of complex materials containing metallic substances such as thallium, lanthanum and yttrium that would superconduct at around -126°C , a temperature warm

Chemical Design Ltd/SPL



station – and an earth wire that conducts current harmlessly to the ground if an appliance fails.

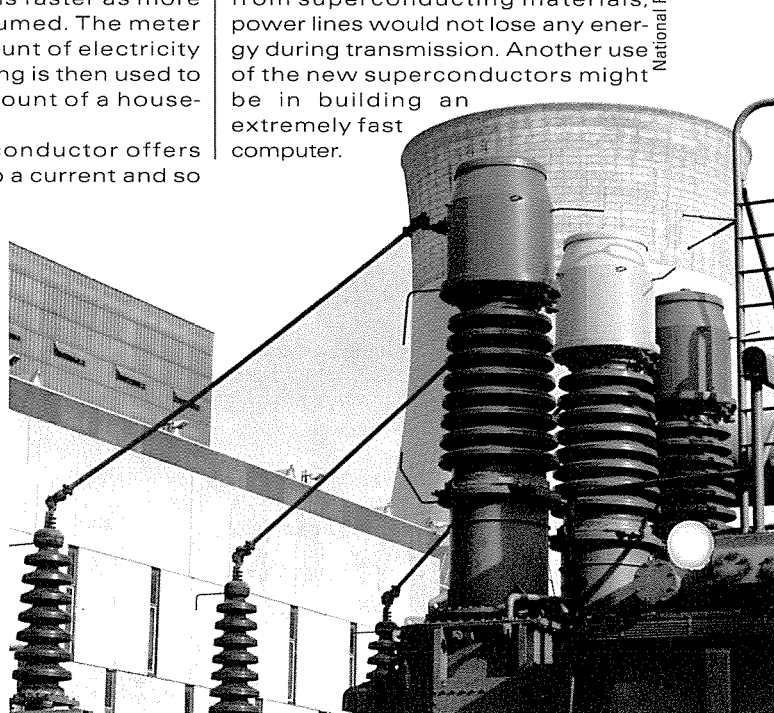
The amount of current entering the house is measured by a meter. This contains a small motor, connected to a counter, that runs faster as more electricity is consumed. The meter clocks up the amount of electricity used and the reading is then used to determine the amount of a household's electricity bill.

Even the best conductor offers some resistance to a current and so

enough to be produced in a school laboratory.

These new materials offer the hope of practical applications for superconductors in the future. One such use might be in a national grid. Made from superconducting materials, power lines would not lose any energy during transmission. Another use of the new superconductors might be in building an extremely fast computer.

National Power



Just amazing!

SHOCKING CURE

A SERIES OF RAPID, 25,000-VOLT SHOCKS. IT HAS BEEN FOUND, IS AN EXCELLENT CURE FOR THE BITE OF DEADLY SNAKES SUCH AS THE SOUTH AMERICAN BUSHMASTER.



Paul Raymond

Power stations transmit electricity at very high voltages, which is stepped down later for safe domestic use. High voltages cut transmission losses, but huge ceramic insulators have to be used to prevent shorting.



Q HI-TECH MINES

Q POWER STATIONS

Q POLLUTION

KING COAL

COAL SUPPLIES A HUGE SLICE of our energy needs, despite its reputation for being a dirty fuel and dangerous to extract. But the image of coal is changing. New technology is revolutionizing mines, while coal-burning is becoming cleaner and more efficient.

Most of the world's coal supplies started to form during the Carboniferous Period, from 360 to 280 million years ago. Decomposed plant matter in a moist environment, such as a swamp, broke down into peat. Buried underground, squeezed and heated, the peat gradually turned into coal, first into lignite, or brown coal, then (as the pressure and heat from above increased) into common bituminous coal, and finally into shiny black anthracite. A layer of peat around 5 metres thick will compress into a seam of coal some 30 cm deep.

As coal seams formed, the pressure forced out oxygen and hydrogen from the plant remains, leaving mainly carbon. Wood contains 50 per cent carbon, while lignite has 70 per cent

and anthracite 94 per cent. It is the carbon that burns, helped by pockets of trapped oxygen and hydrogen gas.

Coal is mined by two distinct methods: surface mining and underground operations. In surface mining – also known as opencast or strip mining – the layers above the coal seams (the

overburden) are stripped away. The overburden can be more than 100 metres deep. The biggest surface mines produce just under 50,000 tonnes of coal a day.

The majority of the world's coal, however, is brought up from underground, from seams as deep as 1,200

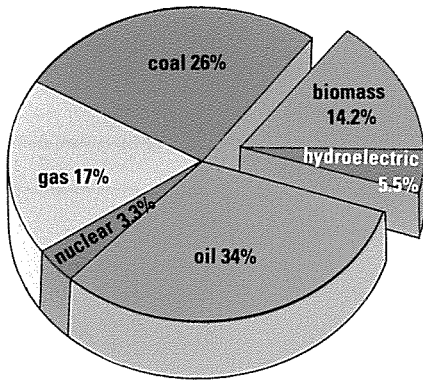
An opencast mine in Germany.

The sides of a surface mine are cut away to form a series of steps called benches. So the deeper the hole, the wider the area it must cover. Much coal, however, is mined underground. This coal face (right), in a mine in Kentucky, USA, is sliced with vertical strokes by a series of cutting edges mounted on a drum.



Spectrum Colour Library

World Consumption of Energy



Mark Franklin

Coal, oil, gas and uranium will all eventually become uneconomic to mine. The top two renewable sources are heat from burning organic matter (biomass) and hydroelectricity.

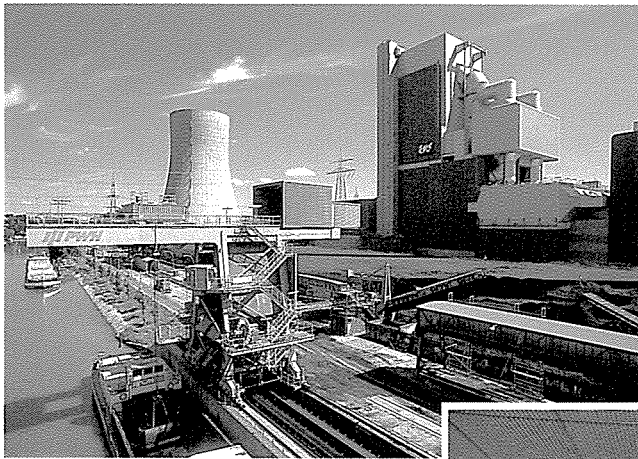
signals back to the console giving the machine's exact position. Sensors around the mine also warn the control-room of that most feared danger – a potentially explosive build-up of methane gas. Other sensors monitor the quality of coal being extracted and tell if equipment needs replacing.

Electricity

The great majority of coal that comes out of the ground is consumed in power stations for making electricity. About 50 per cent of the UK's electrical energy, for example, is supplied by burning coal.

At a power plant, the coal is first pulverized into fine pieces so that it will burn more efficiently. The burning itself takes place in a huge, box-shaped boiler. The inner walls of the boiler contain tubes in which water is converted into steam. The steam passes through a superheater, where its temperature and pressure are in-

Heilbronn power station, run by operators manning computers in a central control room (below), is one of most modern coal-fired power stations in Germany, and one of the largest in the world to have a complete flue-gas cleaning programme.



Energie-Versorgung Schwaben AG

metres below the surface. Geological surveys provide data on which are the most promising seams and how they are laid out. In the most up-to-date mines, cutting machines are steered from a computer console in an underground operations room.

As the excavation proceeds, electronic guiders on the cutter transmit



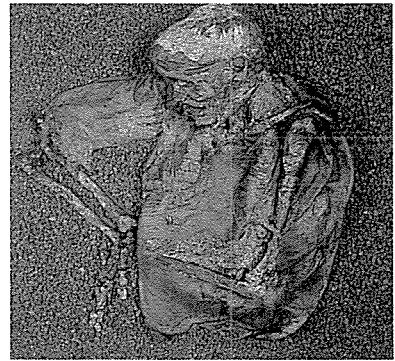
Energie-Versorgung Schwaben AG

creased, before it drives a high-pressure turbine. A shaft from the turbine turns a generator that produces electrical current. A typical boiler consumes 500 tonnes of finely ground coal an hour – enough to generate a million kilowatt-hours of electricity.

Reducing pollution

Burning coal creates a number of problems, however. It contributes to the global 'greenhouse effect' by producing large amounts of carbon dioxide. It also gives off a number of poisonous substances, the worst of which is sulphur dioxide. When sulphur dioxide mixes with water droplets in the air, acid rain forms. This

BURIED IN PEAT



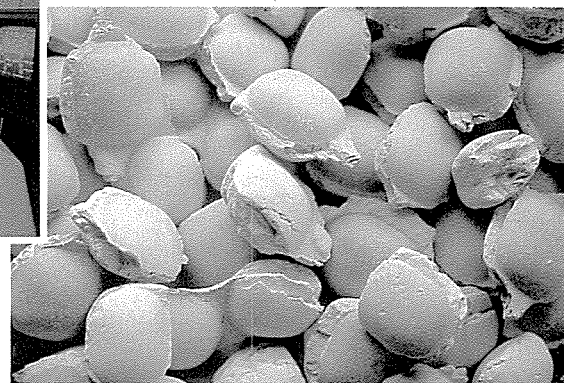
Trustees of the British Museum

As vegetable matter is compressed beneath the living surface of a bog it gradually turns into thick, black peat. Dried and cut into bricks, peat was once used to insulate cottages and it is still burned as fuel in many parts of the world. It is also an amazingly good preservative of animal and human remains. In 1985, for instance, the skin-covered head and upper torso of a man (above) was dug up from a peat-bog near Wilmslow in Cheshire, UK. Analysis showed that he had been garrotted – strangled with a twisted cord – around 2,000 years ago.

has killed millions of trees across Europe and North America.

To reduce their environmental impact, coal-fired power stations are being equipped with a variety of pollution-control systems. The most important of these is a flue-gas-desul-

Gypsum is a by-product of the coal burning process at Heilbronn, produced when limestone slurry combines with the sulphur in waste gas. Pressed into briquettes, it is sold as a building material.



Energie-Versorgung Schwaben AG

phurization system called a scrubber. An alkaline substance, usually lime or limestone, is mixed with water and sprayed on to waste gas coming up the flue. The sulphur dioxide combines with this slurry to form calcium sulphate, or gypsum. In another process, in which crushed coal and limestone are suspended in a blast of air while they are burning, the limestone captures 90 per cent of the polluting gases given off.

Just amazing!

THAT COAL BLACK MAGIC ...

AMONG SOME OF THE MORE SURPRISING PRODUCTS MADE USING COAL ARE NYLON, SACCHARINE SWEETENER, MOTHBALLS, WEEDKILLER AND ANTISEPTICS.



Paul Raymond

Q PRIME MOVERS

Q INDUCTION

Q ROTORS

GENERATORS CONVERT mechanical energy supplied by prime movers—turbines, windmills, high-pressure steam from nuclear reactors and boilers—into electricity. The principle they use is electromagnetism: induction and the basic key to that process is the electron.

Electrons are elementary particles that possess one unit of negative

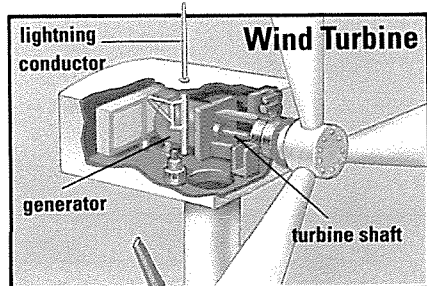
charge. Electrons are a constituent of all atoms, orbiting around the atom's positively charged nucleus. In the crystalline structure of most metals, the outermost electrons are able to detach themselves and become free to move through the material. These free electrons are responsible for the conduction of electricity.

Free electrons can be forced to move under the influence of a magnetic field. If a magnet is moved near a

Small and driven by wind or large and driven by a nuclear reactor, all generators work the same way. A magnet is rotated inside a coil, causing the electrons to move.

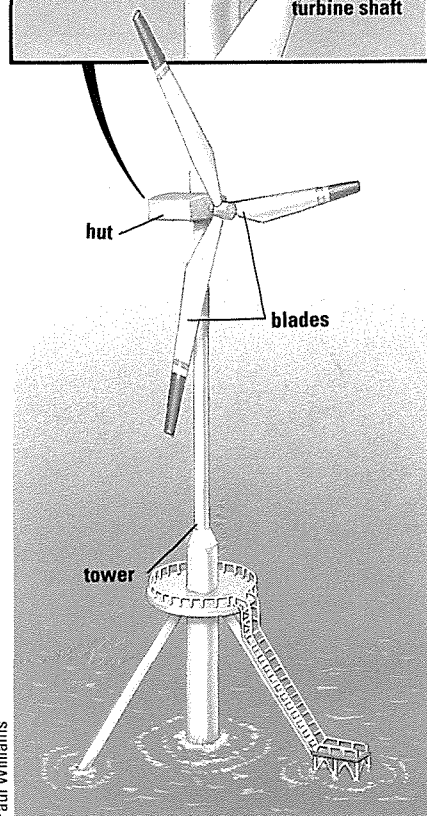
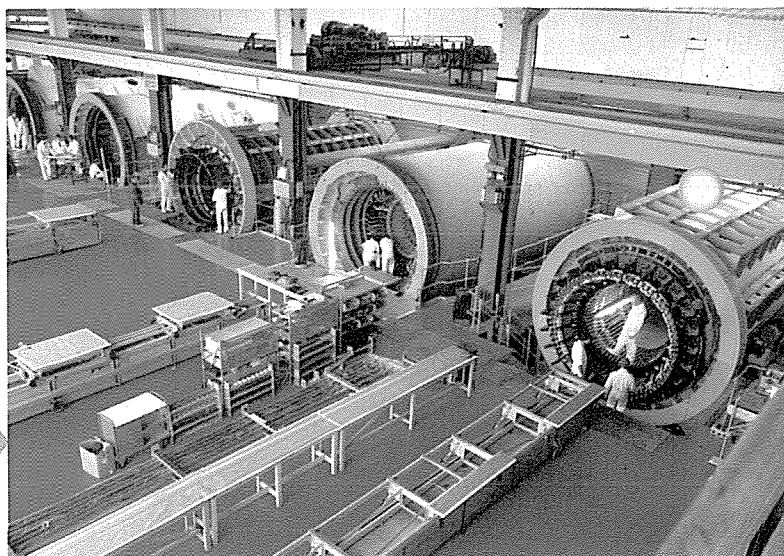
MAKING MEGAWATTS

NEI Parsons



In a wind turbine, the blades are attached directly to the shaft of a generator. The housing is designed to turn the blades into the wind. New 'wind farms' may be built out at sea.

The huge stators have to be wound in strictly controlled clean conditions. On these huge generators tolerances are so fine, dust could cause problems.



Paul Williams

This massive steam turbine will sit in the intermediate pressure cylinder and help turn a 500 MW generator. It will be bolted directly on to the rotor shaft. Most electricity in industrialized countries is produced by steam.

metal wire, an electrical current will be produced. A bigger current will be produced if the wire is wound into a coil, so that the magnet can be near to more of the wire at the same time.

Rotors and stators

Electrical generators consist of a magnet wheel with electromagnetic induction coils on it, sometimes called the rotor, a stationary armature winding, or stator, and a drive system from the prime mover. The rotor is mounted on a shaft which is coupled to the turbine shaft either directly or via a pulley belt. When it turns, it generates electricity in the windings that make up the stator.

The current produced is 'alternating' - that is, it runs one way in the wire, stops, then runs the other way. Alternating current - or AC - reverses itself 50 or 60 times a second, so rather than moving down the wire,

the electrons vibrate. Energy is transferred down the wire as the electric field of each electron affects the next. AC has a great advantage over the 'direct' current - or DC - you get from a battery that only runs one way. AC voltages can be stepped up and down using a transformer.

Transformers

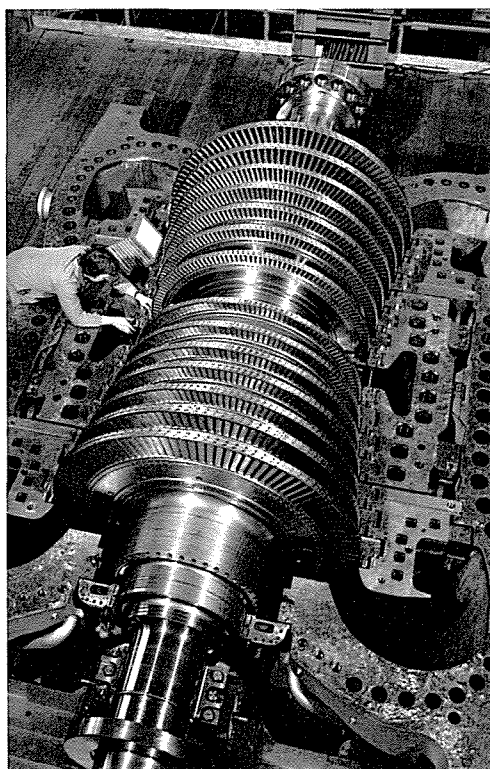
In the largest modern generators, electricity is generated at about 25,000 volts but for efficient transmission over long distances the voltage is increased by transformers to 132,000, 275,000 or 400,000 volts. Once the electricity has reached

industries, and 220 volts or 110 volts is used in the home.

The initial energy which drives the turbine that turns the generator can come from a number of sources, depending on what is cheapest or most convenient in any particular area. In the UK, for example, the steam that drives the turbines is produced from water heated by burning coal or oil, both of which are relatively abundant fuels. Some power stations use nuclear fission to heat the water.

Nuclear power

Whatever method is used to heat the steam, once it has passed through the turbines it must be cooled down again. This is done by dropping the hot water down through the air in huge cooling towers. These wasted concrete structures dominate the landscape around a power station, emitting nothing more harmful than steam. Sadly, the need to cool the water down means that power generation is a very wasteful process. Only about 35 per cent of the heat is converted into electricity, even in the most efficient power stations.

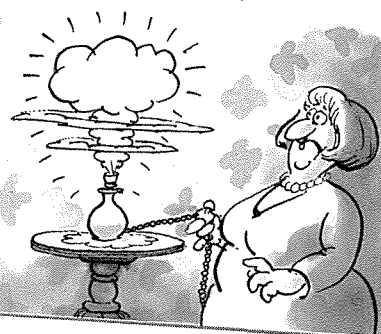


GEC Alsthom

Just amazing!

FUEL EFFICIENCY

IN A MAGNOX NUCLEAR POWER REACTOR, AS MUCH ELECTRICITY CAN BE PRODUCED FROM ONE TONNE OF NATURAL URANIUM FUEL AS FROM 20,000 TONNES OF COAL.



Paul Raymond

FREQUENCY

AM AND FM RADIO

HIGH-DEFINITION TV

RIDING

THE WAVES

TURN ON THE TELEVISION or radio and you are tuning into invisible waves of energy that carry the sound and picture information of programmes into our homes.

Radio waves are a form of electromagnetic radiation. In other words, the waves are made up of vibrating electric and magnetic fields that move at the speed of light.

Radio waves are sent out when an electric current moves very quickly back and forth along a transmitting aerial. The number of to-and-fro

movements – and, therefore, the number of waves – each second is called the frequency. The frequency of a wave is measured in thousands of cycles per second, or kilohertz (kHz), and millions of cycles per second, or megahertz (MHz).

A simple oscillating radio signal, however, is no use for transmitting information. The varying sounds of a human voice or musical instrument have to be superimposed on the basic 'carrier' wave.

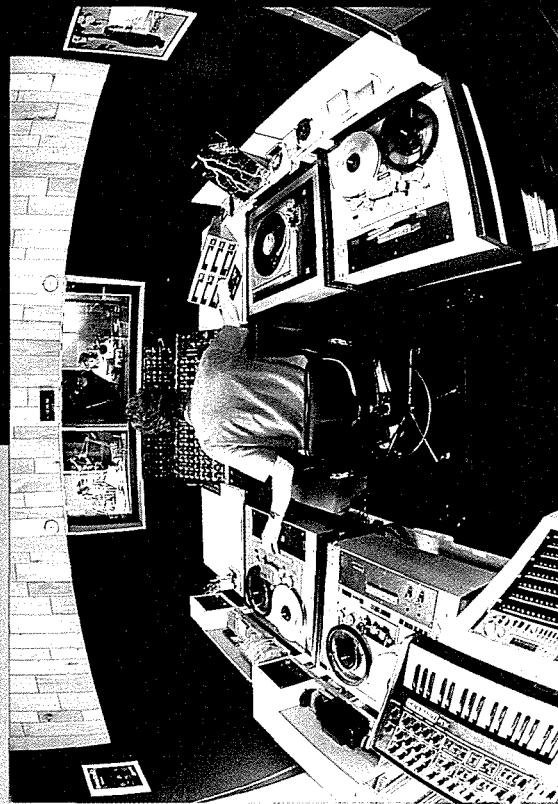
One way to do this is by amplitude modulation (AM). In AM broadcasting, the sounds recorded in the studio are used to control the height of the carrier wave that is sent out. The receiver then separates these changes in amplitude of the carrier wave and passes them to a loudspeaker.

Quality broadcasting

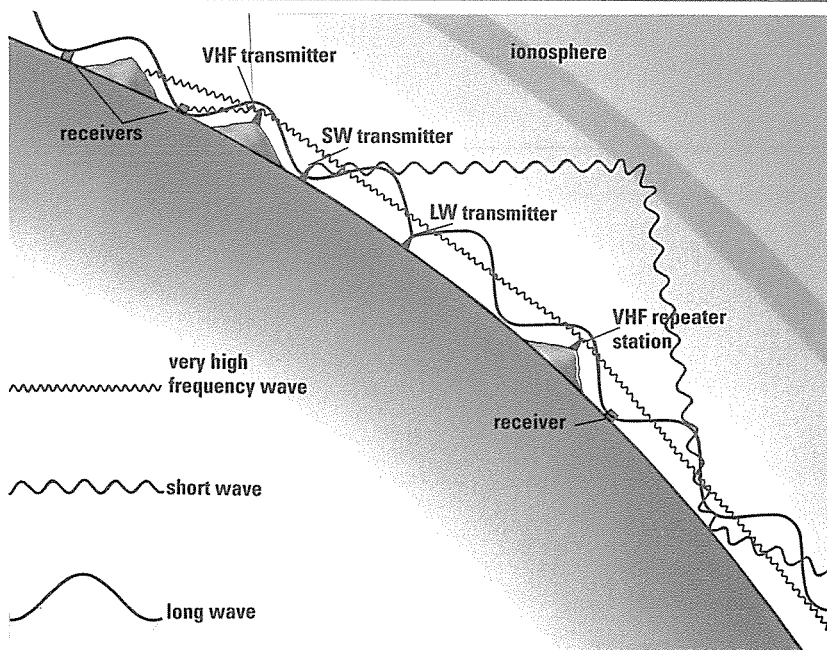
Another method of broadcasting is by frequency modulation (FM). Here, the studio sound modifies the basic frequency of the carrier wave. One big advantage of FM is that it is less affected by interference and can transmit signals of higher quality.

Both types of modulation, AM and FM, are used for broadcasting television programmes. The sound part of the signal is sent out as an amplitude modulation of the carrier wave, while the picture information travels as a frequency modulation. The receiving set then extracts the two different

Transmitting antennae broadcast the carrier waves that have been modulated with the signals from the studio (below) by the transmitters. The transmitting aerial is the white rod at the top of the masts



RADIO WAVE FREQUENCIES



Different radio frequencies have their own individual properties. The highest frequencies will carry most information (such as television signals or stereo radio) but will only travel in straight lines, so they are best suited to local radio. Booster transmitters are needed for wide coverage of a station.

Short-wave signals will reflect off layers of charged particles in the

ionosphere and the Earth's surface. They have long been used for worldwide transmissions, but they can only offer transmissions of limited quality.

Long wave or low frequency signals will spread across a whole nation and beyond from one transmitter. However, there is little room on the airwaves for many stations as each needs a wide band of frequencies.

signals, using one to generate sound through a loudspeaker and the other to produce a moving picture on the television screen.

Big bandwidths

Television broadcasts go out on either very high-frequency (VHF) or ultra high-frequency (UHF) wavebands, ranging up to 850 MHz. The reason is that the higher the frequency, the greater the bandwidth – that is, the range of frequencies that the carrier wave can transport. In turn, the greater the bandwidth, the more information can be carried. So, high-frequency radio waves are

always used for broadcasting video signals and high-fidelity sound.

A television picture is formed by a beam that scans the entire screen in a series of horizontal lines. This happens rapidly – 50 times a second. Present-day television in most of

High-definition TV cameras in action. HDTV will change the shape of the screens in our homes. It has a width-to-height ratio of 5:3, instead of the current 4:3.



R Adshead/TRH Pictures

Just amazing!

MEGA MAST

THE TALLEST RADIO MAST IN THE WORLD, IN NORTH DAKOTA, USA, STANDS 629 METRES HIGH AND WEIGHS 500 TONNES – THE SAME AS 100 ELEPHANTS.



Paul Raymond

Europe uses 625 scan lines. This compares with 525 lines in America and Japan.

To give better pictures, more lines and wider screens are necessary. A new development called high-definition television (HDTV) will use 1,250 lines and screens that are shaped more like those in cinemas. However, this will require the transmission of higher frequencies, because the signal must change faster to carry the extra, more detailed information. This in turn necessitates the use of a much greater bandwidth.

Splitting the data

Ordinary television signals use a 6 MHz bandwidth. HDTV pictures broadcast in the same way would need a bandwidth of 25 to 30 MHz. But this is out of the question because



The British Army employs combat telephones. They use VHF at 30-60 MHz, have a range of 3-24 km depending on the terrain and are fitted with scramblers.

our airwaves are already overcrowded. Instead, engineers are developing ways to shrink the necessary bandwidth by throwing out unwanted bits of picture information. The final broadcast signal will only carry information about the changing parts of the picture, leaving memory chips inside each HDTV set to fill in the parts of the picture that remain still.

Philippe Plailly/Science Photo Library

EYE IN THE SKY

DISAPPEARING RESOURCES could spell disaster for planet Earth, but remote sensing satellites, high above in the sky, hold the key to uncovering minerals, vegetation and even water that cannot be seen from the surface.

It is now quite clear that the Earth's energy resources are finite, that the most important single resource on Earth is fresh water and that food supplies need to be monitored due to the unprecedented growth in population. The data received from remote sensing satellites provides compre-

hensive information in the areas of geology, hydrology and agriculture in a fraction of the time and cost of previous methods. This is because a satellite can take a picture of large areas of the Earth in seconds whereas it would take aircraft several years to photograph the same region.

Although the satellite is more expensive than an aeroplane, it covers a bigger area and takes many more pictures. Satellites that orbit the Earth are called remote sensing satellites. This is because they remotely 'sense' what is going on at the surface of the Earth and tell scientists about rock types and structures that may contain valuable fossil fuels or minerals.

The Delta launch vehicle has been used by NASA for many years to send civilian payloads into Earth orbit. It was the launch vehicle for the five Landsat satellites.

Visible light rays

Remote sensing extends the remarkable properties of the human eye into areas that the eye cannot see. Our eyes can detect objects which transmit or reflect light in what we call

Mato Grosso, the 'great woods' in Brazil, covering 800,000 sq km shows the value of Landsat images in mapping remote areas and detailing forest lands for environmental purposes. Forest areas appear blue.

Copyright SPL

David Baker

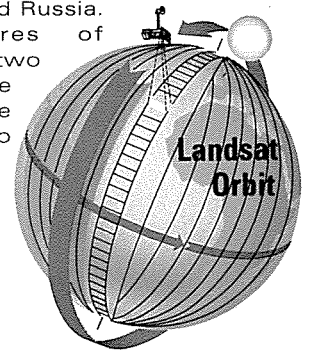


Satrad/Soyuzkarta

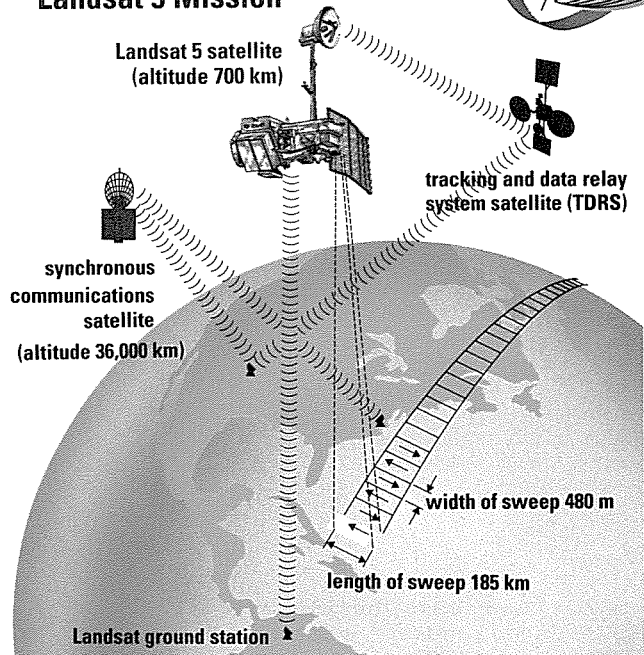
Frankfurt am Main, Germany, taken by a Russian satellite. The river and airport are visible on the left. The colours are natural because the photographs are taken using film unlike Landsat's multi-spectral images. The film is ejected in capsules and sent to Earth to be processed.

different things on the ground.

At present there are only three types of satellite regularly providing remote sensing pictures of the Earth. These are operated by the United States, France and Russia. Satellite pictures of the Earth come in two forms. They can be televised to the ground on radio waves in much the same way that a TV picture gets to the home television set from a



Landsat 5 Mission



the visible part of the electromagnetic spectrum. The whole spectrum covers all known forms of radiation from gamma rays and X-rays through ultraviolet, blue, green, yellow, red and infrared to microwaves and radio waves. Our eyes see only the portion of visible light from blue to red. If, however, our eyes could detect radiation in the ultraviolet or infrared they would see things quite differently.

Satellites are equipped

Sensor data from Landsats 4 and 5 is beamed to White Sands, New Mexico, then via a communications satellite to Goddard Space Flight Center in Maryland, USA.

code called a 'signature' and changes that are easily seen in the infrared are not so readily observed in visible light. For instance, potato blight reflects light brightly in the infrared portion of the spectrum before it is observed in

main transmitter, or they can be shot on film, which is then processed on the ground. The US and the French satellites transmit images to Earth while most Russian satellites send film down to the ground to be processed.

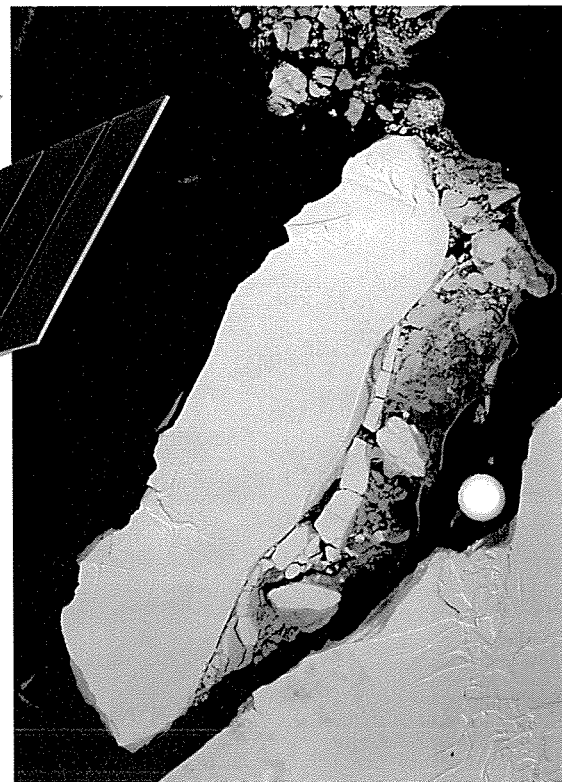
Ice surveillance by Landsat in Antarctica. Such data has been used to navigate routes through ice fields.

Landsat 6 will be equipped with a new sensor to gather more ocean data – showing chlorophyll, plankton and temperature.

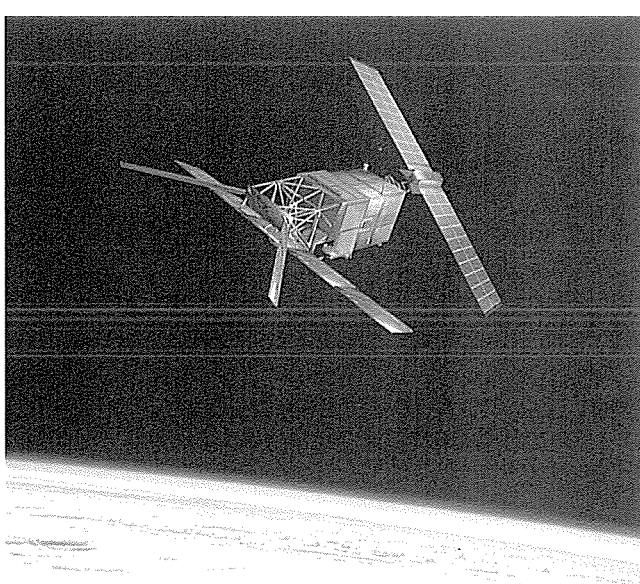
to see things in very narrow parts of the spectrum called bands. This helps them to focus on things that are obscured by the full range of colours available to the human eye. Moreover, they carry sensors that can 'see' into the infrared portion of the spectrum. Because all objects reflect or absorb radiation at different levels they can discriminate between different types of plants, trees, buildings, factories and natural formations, such as rock.

Each object has a unique reflective

the visible bands. The cameras and sensors placed aboard remote sensing satellites are carefully chosen to look at the Earth through 'eyes' that see only certain bands in both visible and infrared light. In this way scientists can break the image into several different parts, concentrating on light reflected from

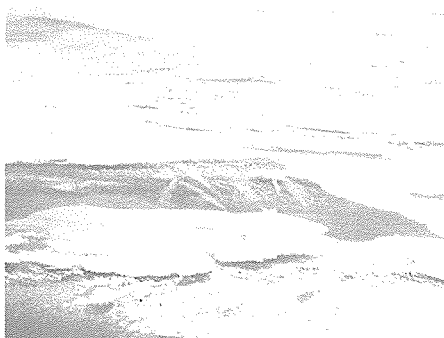


Earth Observation Satellite Co./David Baker



The European remote-sensing satellite (ERS-1), was launched in 1991. It is equipped with all-weather microwave instruments that will be used primarily to study coastal, ocean and polar ice processes. It also collects data for use in the study of climatic change.

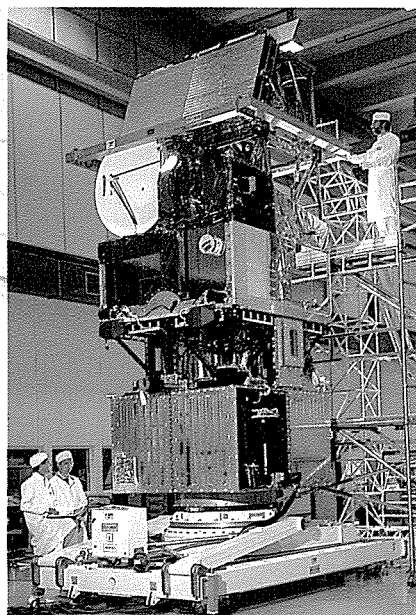
European Space Agency/SPL



Satellites that send their pictures by TV signal circle the Earth continuously for several years. They are very efficient because, unlike satellites that have to be replaced at frequent intervals, they can remain in Space sending back their pictures for many years. The first remote sensing satellite was launched by the US in July 1972. Called Landsat 1, it operated until January 1978, by which time it had been joined by Landsat 2, which had been sent into Space in January 1975. Landsat 3 was launched to join Landsat 2 in March 1978.

Sun-synchronous orbit

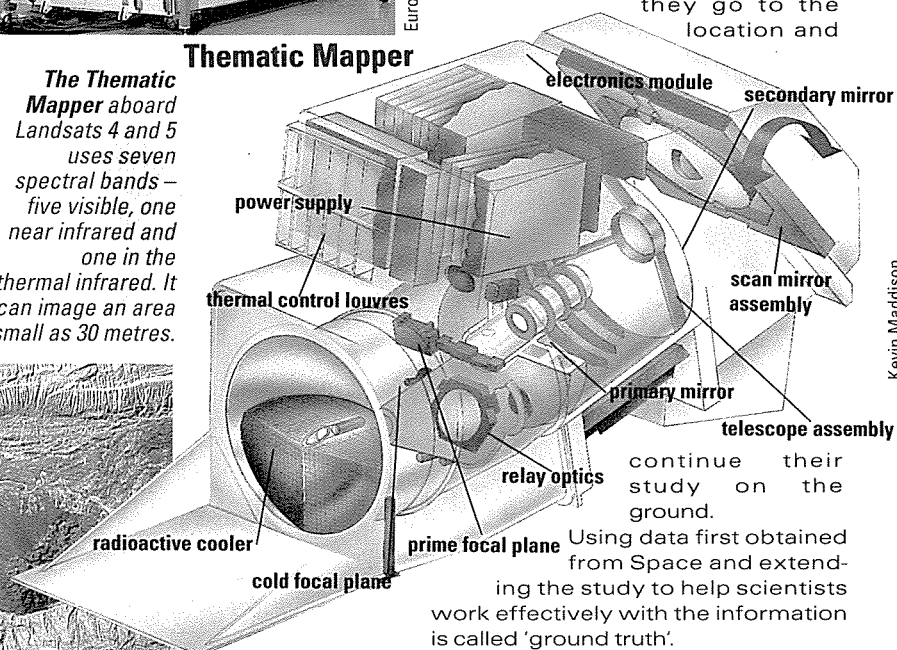
All three Landsats were placed in what scientists call Sun-synchronous orbits. That is, they orbit the Earth at just the right height and orbital inclination to pass over the same spot on the



European Space Agency/SPL

The Thematic Mapper aboard Landsats 4 and 5 uses seven spectral bands – five visible, one near infrared and one in the thermal infrared. It can image an area as small as 30 metres.

Thematic Mapper



Kevin Maddison

Thematic mapper image that shows potential oil sites in Iran. Each 185 km x 177 km Landsat Thematic Mapper scene contains approximately 273 million picture elements (pixels).

ground at the same time every 18 days. Moreover, circling the Earth at a height of about 920 km satellites in this type of orbit pass over the equator at the same local time each day. By using a constant source of lighting on repetitive orbits, scientists are provided with images of the ground below that allow them to compare directly one image with another. In this way, changes can be detected without the added confusion of different lighting angles.

When scientists have found something by satellite that requires further analysis and examination they go to the location and

Using data first obtained from Space and extending the study to help scientists work effectively with the information is called 'ground truth'.

The specific areas of interest that they are looking for are:

- crop health and growth rate
- how the seasons change the condition of agricultural land
- how forests are affected over time with different growing conditions between summer and winter
- which areas are affected by melting ice from winter glaciers

These are just a few reasons for

DATA RECEPTION

To speed distribution of vital remote-sensing information, countries can build low-cost ground receivers with dish antennas that receive images as the satellite passes overhead. Thailand, India, Brazil and Australia are only some of the countries that receive satellite data this way to watch the health of crops over large areas, map rivers and lakes in remote areas or monitor pollution levels. It is just as important to distribute the information efficiently as it is to receive images from the satellites.

studying images from Space. There are many others too.

Marine resources are important because people in many countries rely on fish as a staple part of their diet. Landsat monitors pollution in estuaries and coastal regions, areas called inshore ocean or sea zones. Man-made pollutants not only destroy the environment, they can also travel thousands of kilometres from where they originate, destroying life far from the source. Satellites can track pollutants as they are carried by rivers to the seas and oceans, helping direct attention to where corrective measures are most needed.

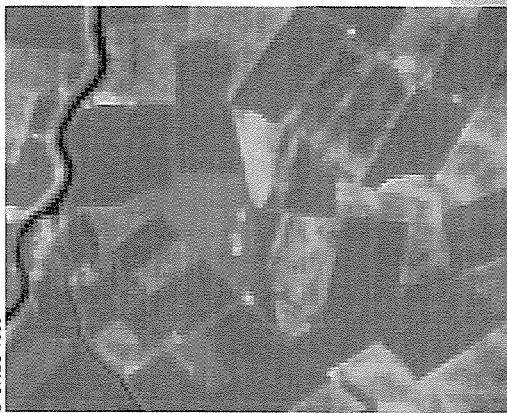
Spot satellite

By the early 1980s the first three Landsat satellites had proved their worth. More advanced than Landsats 1, 2 and 3, Landsats 4 and 5 were launched in 1982 and 1984 into orbits 700 km above the Earth, which gave them repeating ground tracks every 16 days. The success with the

information obtained from Landsat prompted other countries to develop their own remote sensing satellites. In 1986 the first French SPOT satellite was launched followed by a second in 1990 and a third in 1993. Japan and India also have remote sensing satellites, MOS-1 and IRS-1A, respectively.

Russian images

In addition to using their own remote sensing satellites that send images down to Earth by television link, Russian scientists operate other satellites which carry film into Space and



Agricultural monitoring data in East Anglia gathered by SPOT – the French remote sensing satellite (above). The dark red fields are cereal crops, the pink fields oil seed rape and the green fields are mainly bare soil.

return it to Earth after two or three weeks. These pictures provide amazing detail, showing objects on the surface of the Earth five metres or less in size. Like the American and the French images, Russian pictures are available to anyone who wants to buy them. Around the world, scientists are using pictures from Space to find new fossil fuel deposits, track the path of pollution on land and at sea, manage

crops more efficiently, search for water in the desert and give geologists the information to find new mineral resources. Without satellites, specialists would not have such a broad knowledge of threats to the environment and neither would scientists understand the planet in the way they do today, helping work toward a world powered by new and cleaner sources of energy.



▲ Already a special type of radar is being used to hunt for murder victims. It is capable of detecting disturbed earth, where a body may have been buried.

▲ Spy-in-the-sky satellites could be used to help find people who are lost in distant and remote areas or perhaps children who have been abducted.

▲ Burglars, hit-and-run drivers, muggers, drug smugglers, armed robbers and rapists could all be traced using satellite surveillance.

ASPIRIN

FLYWHEELS HAVE BEEN USED since the dawn of civilization. A flywheel is found in every car and in many other machines. But scientists are now looking at new ways to use them.

The simplest form of flywheel is a potter's wheel. It stores up energy that is then expended in turning a pot. It also evens out the potter's jerky energy input to make the wheel spin and gives a smooth output of energy when the pot is being turned.

The flywheel is especially useful where you want a large amount of power for a fairly short time, like a few seconds to a few minutes. For example, in a steel or aluminium rolling mill, very high powers are required quite suddenly as the ingot enters the first rollers. In this case a large flywheel buffer is used and helps enormously. Similarly, flywheels can help meet the sudden power demands in large stone crushing machines.

Generating electricity from the wind is another area where modern flywheels are being used. The wind comes in gusts so the output of a wind turbine is not really suitable for direct use in an isolated system - providing electricity for a remote village perhaps. A wind generator might give 45 kW one minute and only 20 kW a minute or two later. This means that people's lights and equipment would be flickering up and down all the time which is quite unacceptable.

Wind turbines

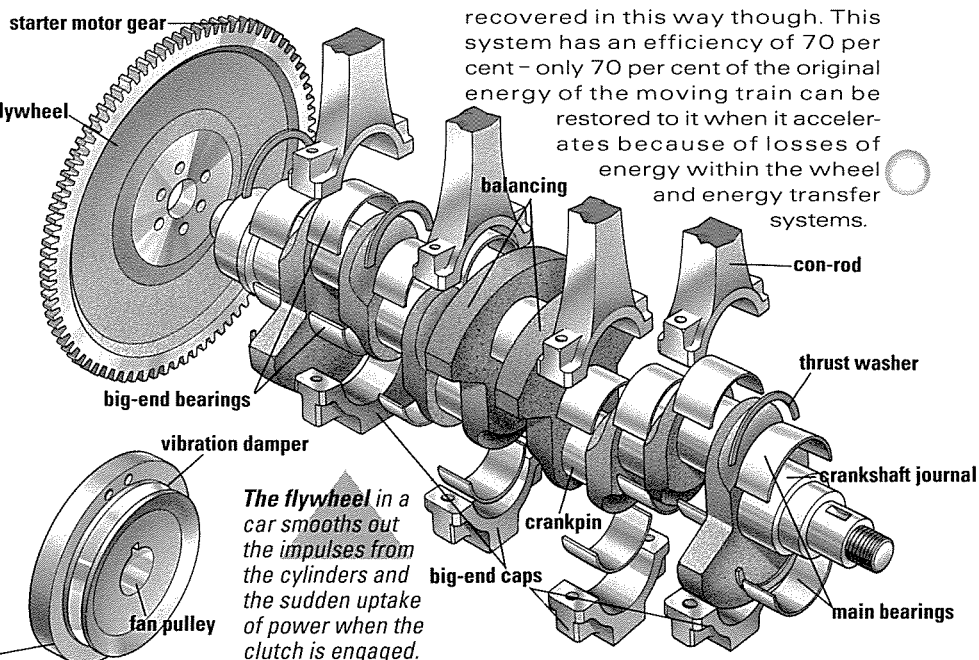
At Rutherford Appleton Laboratory near Oxford, UK, a wind turbine has been developed that uses a one-metre diameter flywheel which can store 3 kWh of energy to smooth the output from a 45 kW wind turbine. This permits a steady electricity flow despite fluctuations in the wind. A back-up diesel engine can be brought on line through an electromagnetic clutch if the wind power and the energy stored in the flywheel get too low. The diesel engine then speeds up the flywheel again and also supplies the customers with electricity until the wind power resumes.

Flywheels have already been used to power transportation in a very imaginative scheme developed by the famous Swiss company Oerlikon. This design featured a type of trolley bus that was powered entirely by flywheel. The system was installed in the pretty Swiss town of Yverdon.

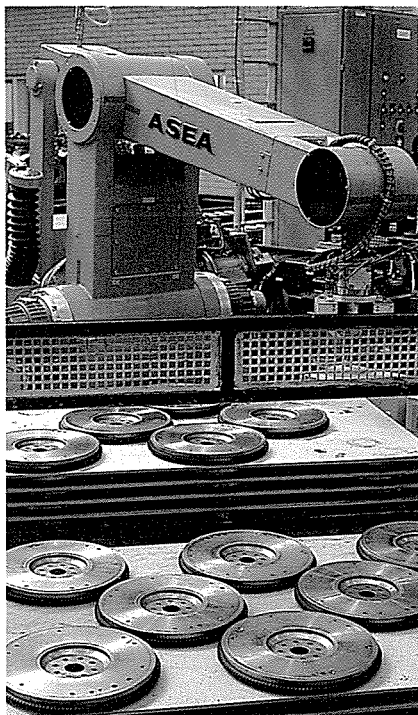
A huge flywheel being built to store energy for a fusion reactor. Far smaller flywheels are used in gyroscopes and are tested for accuracy by laser (right).



The flywheel for this bus had a diameter of 137 cm and a storage capacity of 9 kWh. This could deliver some 75 kW for six or seven minutes. Bus stops were placed a kilometre apart and at each stop the bus would recharge its flywheel. Electricity was taken from an overhead power pylon through a pantograph. It was used to power an electric motor that turned



recovered in this way though. This system has an efficiency of 70 per cent – only 70 per cent of the original energy of the moving train can be restored to it when it accelerates because of losses of energy within the wheel and energy transfer systems.



T McHugh/Science Photo Library

Truck flywheels being installed in diesel engines by industrial robots at the Saab-Scania factory at Södertälje, Sweden.

the flywheel up to speed again. This took 20 seconds at each stop. In spite of its technical success the system has not caught on commercially. The snags were that it has to stop for 20 seconds every kilometre and that it was unable to climb steep hills.

As energy becomes more costly,

flywheels could be used to conserve some of the energy that is wasted when a vehicle brakes. The usual way to do this is to use brake shoes. These convert the vehicle's movement into frictional heat which is then wasted.

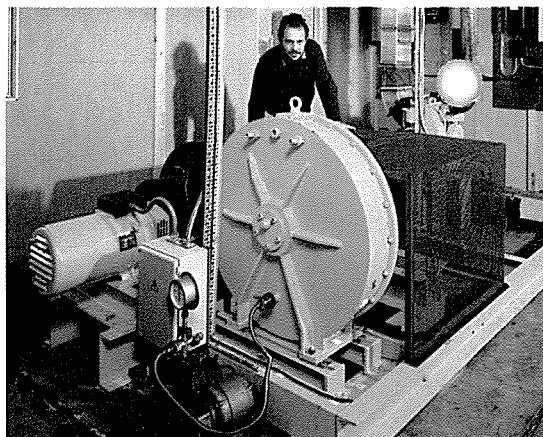
But it is also possible to brake a vehicle by converting the motion into electricity, linking its wheels to a powerful dynamo. The aim is then to use the power from this dynamo to help get the vehicle moving again.

Trackside storage

One plan is to reuse the energy lost when a train brakes by storing it in a trackside flywheel. As the train slows for a station, it can be braked electrically, generating power which feeds into the trackside flywheel by means of a variable speed drive. This flywheel will be about one metre across and will spin at 6,000 rpm.

When the train accelerates out of the station the heavy power requirements can largely be met from the

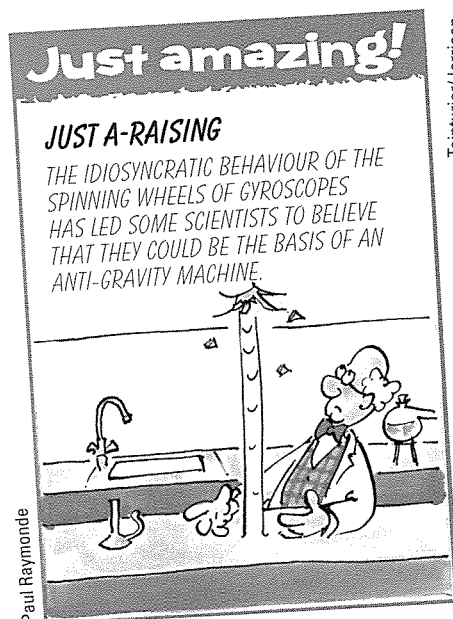
One specialized use of the flywheel is in a gyroscope. This spinning wheel, seen in the simple children's toy, seems to have strange properties. Basically, a spinning wheel tries to maintain a constant orientation in space. This particular property of gyroscopes is used in inertial navigation



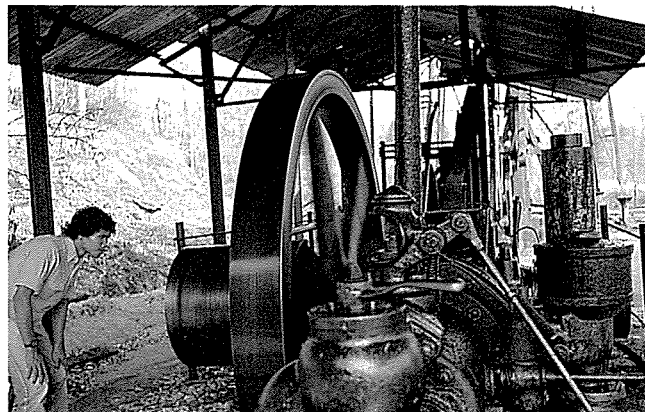
Intermittent energy from wind generators can be smoothed out with a flywheel. A diesel engine can be employed when the wind drops.

Flywheels are not new. They have been used to store energy since ancient times, but came into their own with steam.

Rutherford Appleton Laboratory



Tainturier/Jerrican



trackside flywheel. The motor which speeds the train up is in fact the dynamo to generate the electricity when it slows down. This system avoids the need for a heavy – and dangerous – flywheel on board the train itself.

Not all the braking power can be

systems. The gyroscope is mounted in a set of gimbals which prevent other forces acting upon it. The electrically driven flywheel will then always point in the same direction relative to Space and will appear to turn relative to the Earth like a compass.

GOING FOR A SPIN

IN THE AVERAGE CAR ENGINE only one third of the energy in the petrol is used for driving the vehicle – the rest is wasted. So, inventors are always coming up with new types of car engines, some of which show real promise.

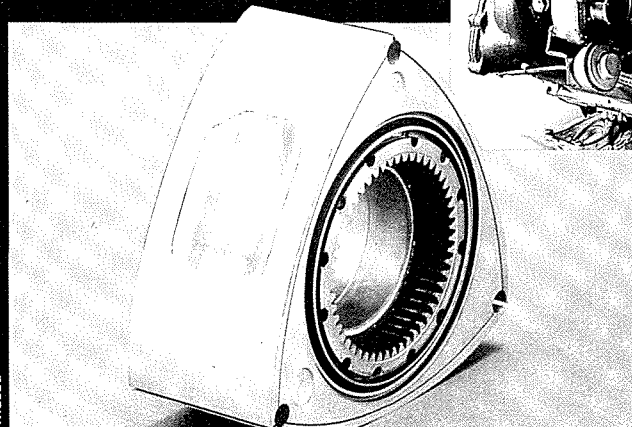
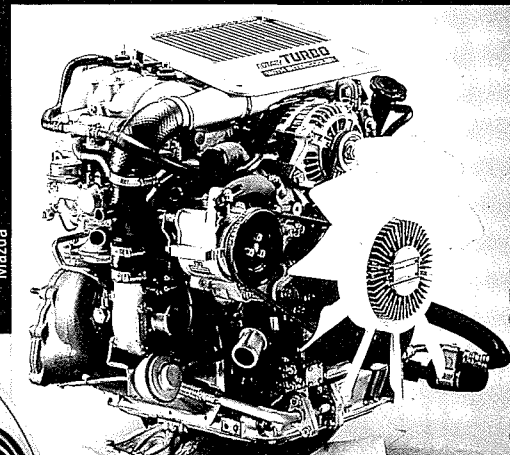
The main problem with the ordinary reciprocating engine fitted to the vast majority of cars is that many of the key parts, such as the pistons and the valves, go up and down thousands of times every minute. By the time the piston reaches maximum speed, it has to stop and start moving in the other direction, losing all of its energy every time it comes to a halt. Modern engines are designed to run at very high speeds, which makes the problem worse.

Slowing the piston

All of the effort that it takes to slow the pistons down and then speed them up again could be used to drive the car forward – if an engine with fewer reciprocating parts could be made to work properly.

The Wankel is the best known kind of non-reciprocating engine. It works

on the same four-stroke cycle as ordinary car engines, but its rotary 'piston' is always turning in the same direction, avoiding wasteful stopping and starting. There have been experimental Wankel engines since the 1950s, but the first production car with one was the NSU Wankel Spyder in 1964. At the time, many people thought that the Wankel would soon make piston engines obsolete, but the Wankel had



A Wankel engine looks little different from a reciprocating engine – except that its piston has a toroidal shape (left) with a combustion recess in it.

Mazda have continued to develop the Wankel engine. In their RX-7, its smooth performance is praised.

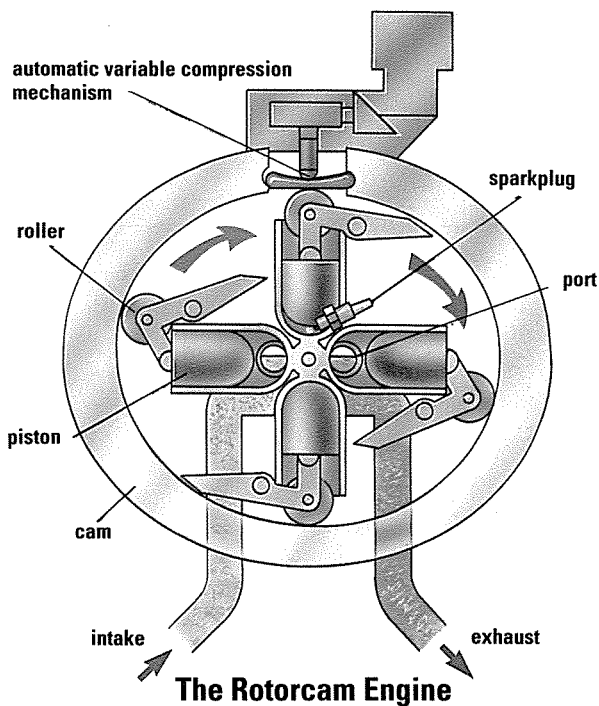


its own problems. It was difficult to seal the edges of the rotor to stop gases leaking past – and the seals in the tips of the rotor wore out very quickly. Also, the fuel consumption of a Wankel engine is often 20 per cent or more higher than a comparable conventional engine.

Sarich orbital

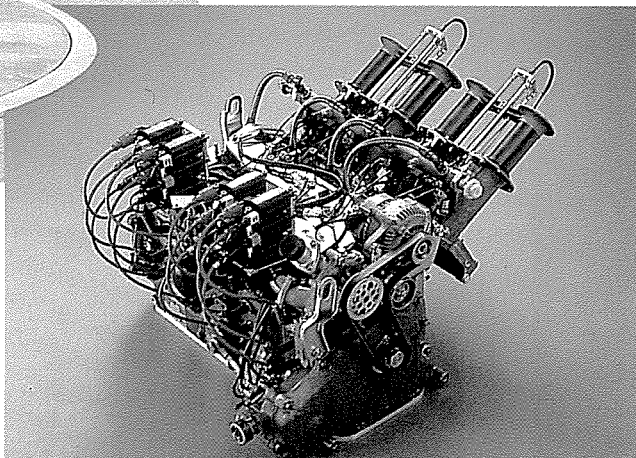
Another innovatory engine was the brainchild of Ralph Sarich. While closely resembling the Wankel engine, the piston inside the Sarich engine does not rotate. Instead, its piston, which is roughly circular, 'orbits' inside the engine housing so that the

The Japanese car manufacturer Mazda's continuing commitment to the Wankel concept has led to the development of the triple rotor engine (below right). This joins three cylinders – each with their rotor – to give smoother running and more power from an engine only slightly enlarged.



Mark Franklin

The Rotorcam engine promises a smaller engine whose compact dimensions make it better suited to modern low-slung cars. Its four cylinders are mounted on a central shaft and revolve inside an oval housing.



Rotorcam. This is a reciprocating piston engine but it does away with the camshaft, flywheel, distributor and water pump, and can run on many different kinds of fuel. The Rotorcam has four pistons, each one going up and down inside a cylinder, but the four cylinders are joined together in the shape of a cross and the whole assembly rotates inside an oval engine housing.

Oval housing

Each piston is connected to a wheel which runs on the inside of the oval housing, so that the piston goes up and down in the cylinder as the engine turns. There are ports – holes – in the sides of the cylinders, which let fuel and air into the cylinder. As the engine rotates, the piston is pushed up into the cylinder and the mixture of fuel and air is compressed. The cylinder then passes a spark plug which ignites the mixture and, finally, the port in the cylinder goes past the exhaust passage so that the burnt gases can flow out of the cylinder, making way for a fresh charge of fuel and air.

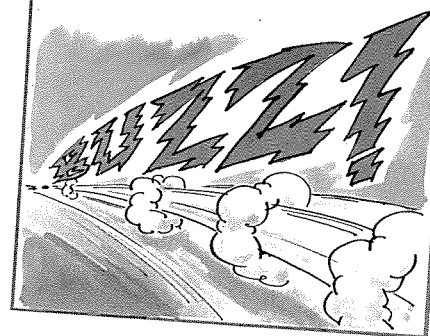
The Rotorcam cannot go off tune and can run at very high tempera-

tures, so it promises to be very efficient. Another attraction is that it is compact. The prototype measures less than a metre across and is only 25 cm high. This shape would make it easy to fit into today's low-slung cars.

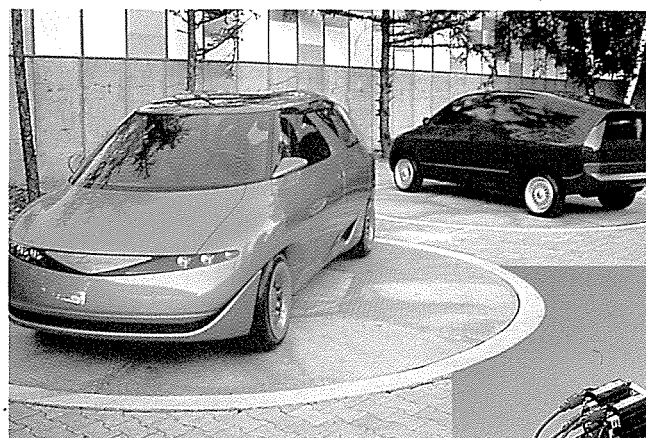
Just amazing!

WONDER WANKEL

THE WANKEL ENGINE IN THE MAZDA RX-7 RUNS SO SMOOTHLY AT HIGH SPEEDS THAT THE MAKERS HAVE FITTED A BUZZER TO WARN THE DRIVER WHEN THE CAR IS REACHING TOP SPEED.



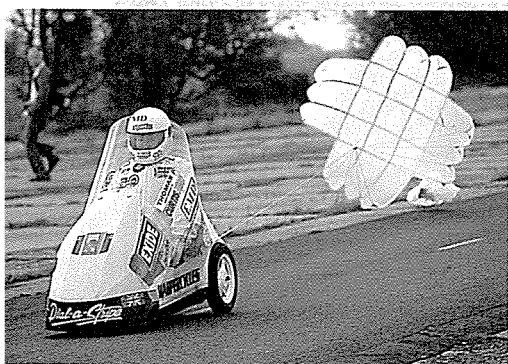
Paul Raymond



Mazda

shape of each combustion chamber can change as it goes through the four-stroke cycle of intake, compression, ignition and exhaust. Sarich also planned similar engines which could run as two-strokes or as diesels. His

THE SUPER C5



The Sinclair C5 was an early attempt at a mass-market electric car. It failed in the early 1980s. However, a British enthusiast has added two three-horsepower engines, giving it a top speed of 112 km/h. But electric power is as polluting as using petrol engines. While electric cars give off no pollution, the power station and factories that charge or make the batteries do.

work attracted a lot of attention world-wide and major manufacturers like Renault became interested. Prototypes are now running and they could be in production by 1998.

Another prototype engine is the